Dissertation on

A MORPHOLOGICAL STUDY AND MORPHOMETRIC ANALYSIS OF THE JUGULAR FORAMEN

Submitted in partial fulfillment for

M.D. DEGREE EXAMINATION
BRANCH- XXIII, ANATOMY

Upgraded Institute of Anatomy
Madras Medical College & Rajiv Gandhi Government General Hospital,
Chennai - 600 003

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

CHENNAI – 600 032

TAMILNADU

APRIL-2016

CERTIFICATE

This is to certify that this dissertation entitled

"A MORPHOLOGICAL STUDY AND MORPHOMETRIC ANALYSIS OF THE JUGULAR FORAMEN"

is a bonafide record of the research work done by **Dr. PREFULLA.P.R**, Post graduate student in the Institute of Anatomy, Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai-03, in partial fulfillment of the regulations laid down by The Tamil Nadu Dr. M.G.R. Medical University for the award of M.D. Degree Branch XXIII-Anatomy, under my guidance and supervision during the academic year from 2013-2016.

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CERTIFICATE OF APPROVAL

To
Dr. Prefulla P.R.
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Dear Dr. Prefulla P.R.

The Institutional Ethics Committee has considered your request and approved your study titled **"A morphological study and morphometric analysis of the Jugular Foramen". No.23122014.**

The following members of Ethics Committee were present in the meeting held on 02.12.2014 conducted at Madras Medical College, Chennai-3.

1. Dr.C.Rajendran, M.D.,	: Chairperson
2. Dr.R.Vimala, M.D., Dean, MMC, Ch-3	: Deputy Chairperson
3. Prof.B.Kalaiselvi, M.D., Vice-Principal, MMC, Ch-3	: Member Secretary
4. Prof.R.Nandini, M.D., Inst.of Pharmacology, MMC	: Member
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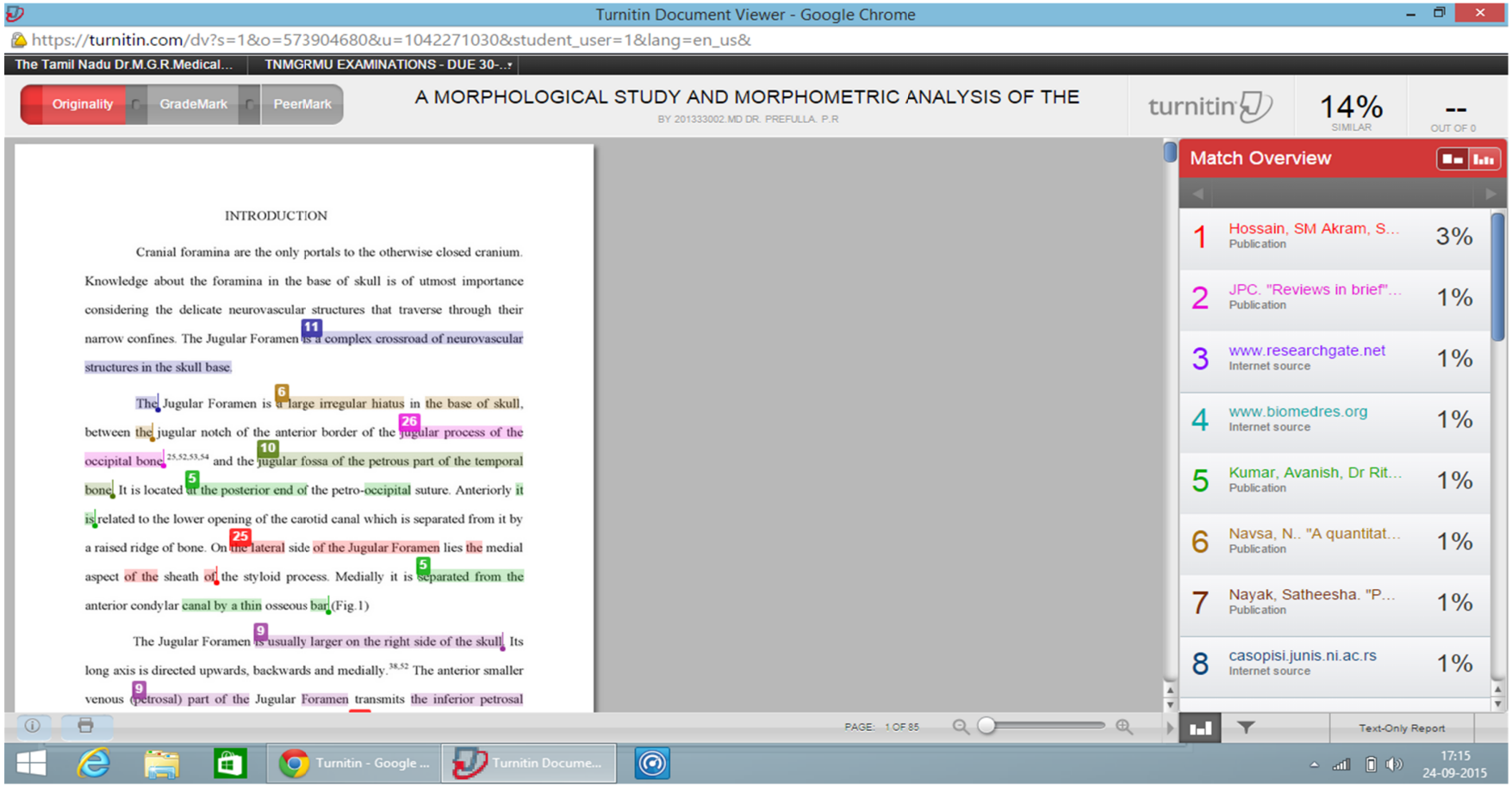
11. Thiru S.Govindasamy, B.A., B.L.,	: Lawyer
12. Tmt.Arnold Saulina, M.A., MSW.,	: Social Scientist

We approve the proposal to be conducted in its presented form.

The Institutional Ethics Committee expects to be informed about the progress of the study and SAE occurring in the course of the study, any changes in the protocol and patients information/informed consent and asks to be provided a copy of the final report.

MEMBER SECRETARY
INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE
CHENNAI-600 003

Member Secretary, Ethics Committee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INTRODUCTION
Cranial foramina are the only portals to the otherwise closed cranium. Knowledge about the foramina in the base of skull is of utmost importance considering the delicate neurovascular structures that traverse through their narrow confines. The Jugular Foramen is a complex crossroad of neurovascular structures in the skull base.
The Jugular Foramen is a large irregular hiatus in the base of skull, between the jugular notch of the anterior border of the jugular process of the occipital bone [25,52,53,54] and the jugular fossa of the petrous part of the temporal bone. It is located at the posterior end of the petro-occipital suture. Anteriorly it is related to the lower opening of the carotid canal which is separated from it by a raised ridge of bone. On the lateral side of the Jugular Foramen lies the medial aspect of the sheath of the styloid process. Medially it is separated from the anterior condylar canal by a thin osseous bar (Fig.1)
The Jugular Foramen is usually larger on the right side of the skull. Its long axis is directed upwards, backwards and medially. [38,52] The anterior smaller venous (petrosal) part of the Jugular Foramen transmits the inferior petrosal
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Above all, I thank the **Almighty**, who has showered his blessings on me and helped me complete this study successfully.

LEGEND

APD	-	Anteroposterior Diameter
FJD	-	Depth of Jugular Fossa
FJW	-	Width of Jugular Fossa
FM	-	Foramen Magnum
IJV	-	Internal Jugular Vein
JB	-	Jugular Bulb/ Superior bulb of internal jugular vein
JF	-	Jugular Foramen
Lt AJF	-	Area of left Jugular Foramen
MLD	-	Mediolateral Diameter
PCC	-	Posterior Condylar Canal
‘p’ value	-	Probability of observing the difference by chance
Rt AJF	-	Area of right Jugular Foramen
SD	-	Standard Deviation

CONTENTS

A MORPHOLOGICAL STUDY AND MORPHOMETRIC ANALYSIS OF THE JUGULAR FORAMEN

ABSTRACT

The Jugular Foramen is a complex crossroad of neurovascular structures at the skull base. Anomalies of the jugular bulb, glomus jugulare tumours, schwannomas, metastatic lesions and infiltrating inflammatory processes attract the clinicians attention to this region.. Knowledge of the anatomy of Jugular Foramen is vital for a favourable surgical outcome in the technically challenging operations of this region.

This study was aimed at analysing the Jugular Foramen morphologically and morphometrically. 100 adult human dry skulls at the Institute of Anatomy, Madras Medical College were used for the study. The features of the Jugular Foramen and Jugular Fossa were studied sincerely and the numerical data obtained were analysed statistically.

In the present study it was found that the mean mediolateral diameter of the Jugular Foramen was 14.87+/- 2.47mm on the right side and 13.76+/- 2.37mm on the left side. The mean anteroposterior diameter of the Jugular Foramen was 11.90 +/-1.93mm on the right side and 10.88+/-1.82mm on the left side. The mediolateral diameter and anteroposterior diameter of the Jugular Foramen exhibited positive correlation. The mean area of the right Jugular Foramen was 179.23+/- 49.39mm^2 and the same of the left Jugular Foramen was 151.65+/-

43.58mm^2. The Jugular Foramen showed side dominance in most of the specimens. Right side was dominant in 69% and left side was dominant in 25%. The mean width of the Jugular Fossa was 7.90+/-1.80mm on the right side and 7.40+/-1.66mm on the left side. The mean depth of the Jugular Fossa was 11.20+/- 3.07mm on the right side and 10.05 +/- 2.85mm on the left side. The width and depth the Jugular Fossa exhibited positive correlation. The Jugular Foramen and Jugular Fossa exhibited statistically significant asymmetry in size. Domed Jugular Fossa was present bilaterally in 69%, unilaterally on the right side in 22%, unilaterally on the left side in 5% and was bilaterally absent in 4%. The Jugular Foramen was partitioned by one septum in 32% on the right side and 29% on the left side. The incidence of complete septum was 17% on the right side and 15% on the left side. The incidence of incomplete septum was 16% on the right side and 13% on the left side. Tripartite Jugular Foramen was present in 1% of skulls, bilaterally. An accessory opening was present in the posteromedial wall of the Jugular Foramen in 7% on the right side and 4% on the left side. In 91% it led to the posterior condylar canal and in 9%, the other end of the canal opened at the posterior margin of foramen magnum. The findings of the present study supported the features of Jugular Foramen reported in the Indian subcontinent. The findings were found to be dissimilar to those of foreign studies suggesting racial variations in the features of Jugular Foramen.

The data obtained will be useful for neurosurgeons and otorhinolaryngologists for achieving a less morbid and more favourable outcome in surgeries of the Jugular Foramen region. The findings are also enlightening to anthropologists, radiologists and anatomists.

KEY WORDS: Jugular Foramen, Septum, Dominance, Jugular Fossa, Dome, Jugular Bulb.

Introduction

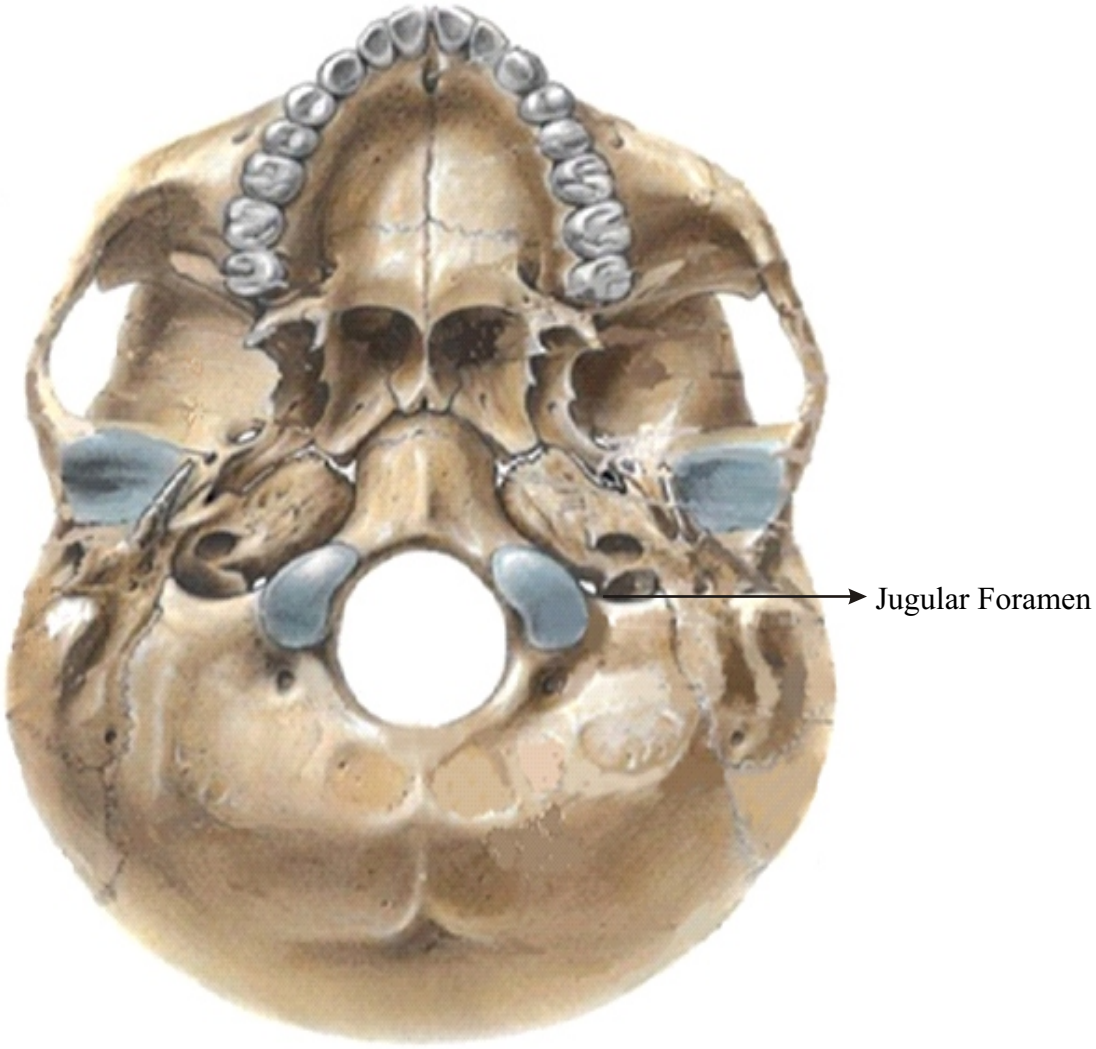


Fig.1: Base of skull

INTRODUCTION

Cranial foramina are the only portals to the otherwise closed cranium. Knowledge about the foramina in the base of skull is of utmost importance considering the delicate neurovascular structures that traverse through their narrow confines. The Jugular Foramen is a complex crossroad of neurovascular structures in the skull base.

The Jugular Foramen is a large irregular hiatus in the base of skull, between the jugular notch of the anterior border of the jugular process of the occipital bone [25,52,53,54] and the jugular fossa of the petrous part of the temporal bone. It is located at the posterior end of the petro-occipital suture. Anteriorly it is related to the lower opening of the carotid canal which is separated from it by a raised ridge of bone. On the lateral side of the Jugular Foramen lies the medial aspect of the sheath of the styloid process. Medially it is separated from the anterior condylar canal by a thin osseous bar (Fig.1)

The Jugular Foramen is usually larger on the right side of the skull. Its long axis is directed upwards, backwards and medially.[38,52] The anterior smaller venous (petrosal) part of the Jugular Foramen transmits the inferior petrosal sinus; its intermediate (neural) part transmits glossopharyngeal nerve, vagus nerve and cranial accessory nerve; its

Fig.2: Right Jugular Foramen showing the Jugular Fossa.

posterior larger venous (sigmoid) part transmits the internal jugular vein. [26,52]The jugular foramen contains the transition of sigmoid sinus to internal jugular vein and the termination of inferior petrosal sinus [14], with 60% of the area of all venous foramina of the skull occupied by the jugular foramina.[24]

Where the sigmoid sinus continues as the internal jugular vein, the jugular fossa of the petrous part of temporal bone (Fig. 2) is recessed out upwards and laterally to accommodate the superior bulb of the internal jugular vein, and it separates the same from the tympanic cavity.[13,14,25] Dome of the jugular bulb is generally covered by a bone, which is called the dome of the Jugular Fossa. The lateral wall of the fossa is pierced by mastoid canaliculus, which transmits the auricular branch of vagus nerve (Arnold's nerve). On or near the ridge between the Jugular Foramen and lower opening of the carotid canal lies the canaliculus for the tympanic nerve which transmits the tympanic branch of glossopharyngeal nerve (Jacobson's nerve).[38,52] Other structures that the Jugular Foramen transmits are the meningeal branches of the ascending pharyngeal artery in the anterior compartment and meningeal branch of occipital artery in the posterior compartment.[25]

The lower and posterior borders of the Jugular Foramen are smooth and regular. The bony notch formed by the inferior ganglion of the

Fig.3: Compartmentation of Jugular Foramen

glossopharyngeal nerve is present at the medial end of the sharp upper border of the Jugular Foramen. The apex of this notch may have projecting edges which may reach the occipital bone and divide the Jugular Foramen into two or sometimes three compartments (Fig. 3). The orifice of the cochlear canaliculus lies at the deepest part of this notch.[2,52] However, nowadays authors[21,51,55] more frequently consider this important cranial venous drainage area as a canal and not as a real foramen. They describe its endocranial opening and exocranial opening, both oriented in different planes. Its endocranial opening is triangular and exocranial opening has alembic shape leading into the Jugular Fossa in which the jugular bulb is located.[22]

Aim of the study

AIM OF THE STUDY

A plethora of pathological conditions may occur in the Jugular Foramen, arising from structures within it or from contiguous structures. The neoplastic pathologies tend to alter the normal anatomy of Jugular Foramen by invasion, erosion or expansion. These tumours pose significant diagnostic as well as surgical challenges since they demand a microsurgical approach to this region. The Jugular Foramen varies considerably in size and shape, along with the internal jugular vein.[57]The foramen's complex shape, its formation by two bones, and the delicate neurovascular structures that pass through it further compound its anatomy.

The most common intrinsic lesion in the Jugular Foramen (JF) is hypervascular paraganglioma (glomus jugulare) located in the jugular fossa,[39,60] followed by neurogenic tumours like schwannoma and neurofibroma. Less common lesions include meningioma, haemangiopericytoma, chondrosarcoma, and plasmacytoma.

Extrinsic lesions comprise of metastases from primary tumours in the lung, breast or prostate and malignant tumours arising in adjacent anatomical structures like the nasopharynx, parotid gland and temporal bone. Retrograde perineural spread from malignancies of the face and

oral cavity may give rise to JF metastases. JF fracture may result from trauma to skull base. Endolymphatic sac tumours arising at the posteromedial aspect of the petrous bone can frequently extend to the Jugular Foramen. [55,58,60]

In Computerised Tomography images most tumours of the Jugular Foramen manifest as areas of infiltrative bone destruction, although schwannoma and meningioma cause smooth enlargement of the foramen.[8] Anatomical variants like asymmetrically enlarged Jugular Foramen, high jugular bulb, high dehiscent jugular bulb, or a jugular bulb diverticulum may be misdiagnosed as pseudomasses in the JF.[22,55] In such cases the hypervascular paragangliomas can be ruled out by the presence of preservation of normal bony margins and intact compartmentation by intrajugular process in the asymmetrically but proportionately enlarged JF.[16]

Typically JF tumours produce the Jugular Foramen syndrome (Vernet's syndrome) characterised by IX, X and XI cranial nerve palsy and may produce other related syndromes depending on the extension of the tumour. [49]

Radical removal of benign JF tumours may be curative. Though surgical management of JF tumours is complex and difficult, with

accurate knowledge of the normal anatomy and variations of the region, success can be achieved with reasonable morbidity and mortality rates.[39]Thus the knowledge of morphological details and dimensions of the Jugular Foramen as well as its variations would be of great value to neurologists, radiologists, otorhinolaryngologists and neurosurgeons.

Aim of the present study is to analyse the Jugular Foramen morphologically and morphometrically. Hopefully the data will be useful to radiologists, ENT surgeons and neurosurgeons for preoperative planning and management of Jugular Foramen surgeries.

The parameters studied are:

1. Maximum mediolateral diameter of right and left Jugular Foramina
2. Maximum anteroposterior diameter of right and left Jugular Foramina
3. Area of right and left Jugular Foramina
4. Width of right and left Jugular Fossae
5. Depth of right and left Jugular Fossae
6. Presence of domed right and left Jugular Fossae
7. Number of septa in the right and left Jugular Foramina
8. Type of septum in the right and left Jugular Foramina, whether complete or incomplete.

9. Presence of accessory opening in the walls of right and left Jugular Foramina
10. Site where the accessory opening leads to on the right and left sides.

Review of Literature

REVIEW OF LITERATURE

MEDIOLATERAL DIAMETER OF THE JUGULAR FORAMEN (MLD)

Aydinlioglu A et al[6] (2001) studied Eastern Anatolian skulls and reported that MLD on the right and left sides were 13.7mm 12.3mm respectively.

OE Idowu[34] (2004) studied 40 JF of 20 Nigerian skulls and stated that mean MLD on the right and left sides were 13.90 mm and 14.11 mm respectively.

Ekinci et al[15] (2009) conducted a study on 70 skulls of Turkish population and reported that MLD on the right side (Rt MLD) was 16.0mm and MLD on the left side (Lt MLD) was 15.5 mm.

Namita A Sharma et al[33] (2011) in their study of the foramina of skull base in 50 dry skulls said that the MLD of JF were 15.59+/- 2.64mm and 13.83+/- 4.94mm on the right and left sides respectively.

Ketu Chauhan et al[28] (2011) in their study of 50 dry skulls reported that the MLD were 13.46mm and 13.10mm on the right and left sides respectively.

Anjali Singla et al[4] (2012) studied 50 adult dry skulls and observed that the MLD of the JF were 15.67mm and 14.85mm on the right and left sides respectively.

Osunwoke EA et al[35] (2012) in their study of 120 dry skulls reported that the MLD of the JF were 15.76±0.22mm and 13.39±0.23mm respectively on the right and left sides. They stated that the mean length of the right JF was larger than that of the left JF.

Anitha MR et al[3] (2013) in their study of the JF of 100 adult dry skulls reported that Rt MLD and Lt MLD were 15.21mm and 13.39mm respectively. In 88% of skulls the length of the JF on the right side was more than that of the left side and in 12% of skulls length of the left side JF was more.

Rahul Rai et al[41] (2013) studied 100 dry skulls and observed that MLD of right JF was 12.90mm and the same of left JF was 13.01mm.

Shifan Khanday et al[48] (2013) analysed 648 Jugular Foramina of 324 skulls and found out that Rt MLD and Lt MLD were 14.6 mm and 13.9 mm respectively.

Vijisha P et al[57] (2013) in their study of 30 adult dry skulls reported that Rt MLD was 17.33mm and Lt MLD was 15.30mm.

Avanish Kumar et al[5] (2014) in their study of JF of 68 skulls, stated that the MLD was 13.6mm on right side and 13.9 mm on left side.

Chandni Gupta et al[9] (2014) studied 50 adult dry skulls and reported that Rt MLD and Lt MLD were 16.52 mm and 16.02 mm respectively.

Roma Patel et al[44] (2014) in their study of 100 dry skulls stated that MLD of right and left JF were 12.17mm and 11mm respectively.

N. Himabindu et al[32] (2015) analysed the JF of 110 adult dry skulls and reported that Rt MLD was 14.6mm and Lt MLD was 12.69mm.

ANTEROPOSTERIOR DIAMETER OF THE JUGULAR FORAMEN (APD)

Aydinlioglu A et al[6] (2001) studied Eastern Anatolian skulls and reported that right APD (Rt APD) and left APD (Lt APD) were 12.2mm and 10.9mm respectively.

OE Idowu[34] (2004) studied 40 JF of 20 Nigerian skulls and stated that the mean Rt APD and Lt APD were 10.22 mm and 9.57 mm respectively.

Ekinci et al[15] (2009) conducted a study on 70 skulls of Turkish population and reported that APD on right side was 8.4mm and the same on the left side was 7.6 mm.

Ketu Chauhan et al[28] (2011) in their study of 50 dry skulls reported that APD were 9.9mm and 7.9mm on the right and left sides respectively.

Namita A Sharma et al[33] (2011) in their study of the foramina of skull base in 50 dry skulls said that Rt APD and Lt APD were 9.02+/- 1.79mm and 7.73+/- 1.79mm respectively.

Anjali Singla et al[4] (2012) studied 50 adult dry skulls and observed that APD of the right JF was 9.32 mm and that of the left JF was 7.34mm. They also reported that the width of the JF was more on right side.

Osunwoke EA et al[35] (2012) in their study of 120 dry skulls reported that APD of JF were 9.34±0.18mm and 7.54±0.20mm respectively on right and left sides. They stated that mean width of right JF was larger than that of left JF.

Anitha MR et al[3] (2013) in their study of the JF of 100 adult dry skulls reported that Rt APD and Lt APD were 10.13mm and 8.81mm

respectively. In 74% of the skulls width of the right side was more than that of the left side whereas in 16% of skulls width of the left JF was more.

Rahul Rai et al[41] (2013) studied 100 dry skulls and observed that Rt APD was 8.90mm and Lt APD was 6.91mm.

Shifan Khanday et al[48] (2013) analysed 648 JF of 324 skulls and found out that APD of JF on the right side was 10.06mm and that on the left side was 8.9mm.

Vijisha P et al[57] (2013) in their study of 30 adult dry skulls reported that APD of right JF was 12.13mm and APD of left JF was 9.27mm.

Avanish Kumar et al[5] (2014) in their study of JF of 68 skulls, stated that mean Rt APD was 10.6mm and mean Lt APD was 9.2 mm.

Chandni Gupta et al[9] (2014) studied 50 adult dry skulls and reported that APD were 11.22 mm and 9.52 mm on right and left sides respectively.

Roma Patel et al[44] (2014) in their study of 100 dry skulls stated that APD of right and left JF were 7.9mm and 6.2mm respectively.

N. Himabindu et al[32] (2015) analysed the JF of 110 adult dry skulls and reported that the APD on the right side was 9.61mm and the same on the left side was 8.24mm.

AREA OF JUGULAR FORAMEN (AJF)

OE Idowu[34] (2004) studied 40 JF of 20 Nigerian skulls and stated that mean JF area on the right was 437.49 mm^2 and that on the left was 419.48 mm^2.

Shifan Khanday et al[48] (2013) analysed 648 JF of 324 skulls and found out that the mean area of JF on right side was 118 mm^2 and on left side was 90 mm^2.

Vijisha P et al[57] (2013) in their study of 30 adult dry skulls reported that area of right JF was 210.87mm^2 and that of the left JF was 141.93 mm^2.

Chandni Gupta et al[9] (2014) studied 50 adult dry skulls and reported that mean area of JF were 187.34 mm^2 and 153.2 mm^2 on right and left sides respectively.

SIDE DOMINANCE OF THE JUGULAR FORAMEN

Peter.L.Williams and Roger Warwick[38] (1980) in 'Gray's Anatomy' stated that the Jugular Foramen is usually larger on the right side of the skull.

R R Sturrock[40] (1988) in his study of 156 adult dry skulls observed that the right JF was larger than the left JF in 68.6% whereas the left was larger in 23.1%, no difference in size with side was observed in 8.3%.

MT Hatiboglu et al[30] (1991) did a study on 300 Anatolian skulls of 17th and 18th centuries and reported that in 61.6% the right JF was larger whereas in 26% the left was larger and rest of the specimens had both JF of equal size.

SA Ayeni et al[46] (1995) studied the microsurgical anatomy of JF in 10 cadavers, and reported that the right foramen was larger than the left in 70%, equal in 20% and smaller in 10%.

H.L. Guido et al[19] (1997) studied 100 Brazilian skulls and stated that right JF was larger in 61 %, left was larger in 26 % and both were symmetrical in size in 13 %.

OE Idowu[34] (2004) studied 40 JF of 20 Nigerian skulls and stated that side predominance of one of the JF appeared in 80% of cases. When present, the predominance of right JF was in 55% and that of left JF was in 25%.

Wysocki et al[24] (2006) in their study of 100 adult human dry skulls observed that in 54% of the skulls there was right sided dominance of the JF compared to 27% of the skulls with a left sided dominance. In the remaining 19% of skulls there was symmetry with no side dominance.

MM Patel et al[37] (2007) in their study of 91 skulls stated that 60.4% of cases showed that right foramen was larger than the left foramen whereas 24.2% of cases showed that right foramen was equal to the left and in 15.4% of cases the left was larger than the right.

Keles B et al[27] (2009) studied the JF anatomy by microscopic dissection of 22 cadaveric head specimens and documented that right JF was larger than the left in 72.7%.

Ekinci et al[15] (2009) conducted a study on 70 skulls of Turkish population and reported that right JF was larger than left in 61.4%, left was larger in 24.3% and both were of equal size in 14.3%.

Hussain Saheb et al[20] (2010) studied 125 adult dry skulls and observed that right JF was larger than the left in 64.8% and equal in size to the left in 10.4%. The remaining skulls had a larger JF on the left side.

Ruchira Sethi et al[45] (2011) analysed 56 adult dry skulls and reported that the right JF was larger in 53.5% and left JF was larger in 7.1% skulls. In the remaining 39.4% skulls the JF were equal in size on both sides.

Osunwoke EA et al[35] (2012) studied 120 dry skulls and stated that right JF was larger than the left JF.

SM Akram Hossain et al[50] (2012) studied 55 adult dry skulls and observed that in 58 % right JF was larger than the left, in 22 % smaller and in 20 % right JF was equal in size to the left.

Rahul Rai et al[41] (2013) studied 100 dry skulls and observed that the right JF was larger than the left in 74%, smaller in 19% and both were equal in size in 7%.

Avanish Kumar et al[5] (2014) in their study of JF of 68 skulls, stated that JF was larger on the right side in 64.7% of cases, in 19.1% of cases it was larger on the left side whereas in 16.1% JF of both sides were equal in size.

Roma Patel et al[44] (2014) in their study of 100 dry skulls stated that size of the JF varied on the two sides. The right JF larger than the left were 75%, right smaller than the left were 23% and both were of equal size in 2%.

WIDTH OF THE JUGULAR FOSSA (FJW)

Anjali Singla et al[4] (2012) in their study of 50 adult dry skulls observed that the mean FJW were 8.99mm on the right side and 7.54mm on the left side. They also reported that width of the Jugular Fossa was larger on the right side.

Chandni Gupta et al[9] (2014) studied 50 adult dry skulls and reported that the mean FJW were 6.83 mm and 5.69mm on the right and left sides respectively.

DEPTH OF THE JUGULAR FOSSA (FJD)

Aydinlioglu A et al[6] (2001) studied Eastern Anatolian skulls and reported that mean FJD were 14mm on right side(Rt FJD) and 13.7 mm on left side(Lt FJD).

Ketu Chauhan et al[28] (2011) in their study of 50 dry skulls reported that mean Rt FJD and Lt FJD were 13.08mm and 11.54mm respectively.

Anjali Singla et al[4] (2012) studied 50 adult dry skulls and reported that Rt FJD was 11.11mm and Lt FJD was 11.04mm.

Shifan Khanday et al[48] (2013) analysed 648 JF of 324 skulls and documented that Rt FJD was 10.1mm and Lt FJD was 9.0 mm.

Chandni Gupta et al[9] (2014) studied 50 adult dry skulls and reported that Rt FJD and Lt FJD were 11.58mm and 11.13mm respectively.

Ivan Jovanovic et al[22] (2014) in their study of 37 sagittal sections (17 left and 20 right) of dried adult human skulls reported that Rt FJD was 9.43mm and Lt FJD was 8.10mm.

PRESENCE OF DOMED BONY ROOF OF JUGULAR FOSSA

A.S. Breathnack[1] (1948) in **'**Frazer's anatomy of the human skeleton' stated that the Jugular Fossa is frequently very deep, lodging the bulb of IJV.

R R Sturrock[40](1988) in his study of 156 adult dry skulls found out that dome was present bilaterally in 53.9%, unilaterally on right side in 30.1%, on left side in 6.4% and absent bilaterally in 9.6% specimens. He also stated that dome indicated the presence of superior bulb of IJV.

MT Hatiboglu et al[30] (1991) did a study on 300 Anatolian skulls of 17th & 18th centuries and reported that dome was present bilaterally in 49%, unilaterally on the right side in 36.6% and on the left in 4.6%. A domed roof was not found in the remaining 10.3% of skulls.

H.L. Guido et al[19] (1997) studied 100 Brazilian skulls and stated that dome was present bilaterally in 86%, unilaterally on right side in 10% and left side in 4%.

MM Patel et al[37] (2007) in their study of 91 skulls stated that dome was found bilaterally in 21% and was absent bilaterally in 25.3% of cases.

Hussain Saheb et al[20] (2010) studied 125 adult dry skulls and observed the dome bilaterally in 49.6%, unilaterally on right side in 27.2% and left side in 8.8%. It was absent in 14.4%.

SA Athavale[51] (2010) studied 116 dry skulls and reported that dome was present on right side in 78% and on left side in 69.4%.

Pereira et al[17] (2010) studied 111 dry skulls and observed a domed bony roof in 68.5% of skulls, bilaterally.

Namita A Sharma et al[33] (2011) in their study of 50 dry skulls said that the dome was present bilaterally in 58%, unilaterally on right side in 28% and on left side in 8%.

Anjali Singla et al[4] (2012) in their study of 50 adult dry skulls reported that dome was present bilaterally in 66%, unilaterally in 6% on right side and in 16% on left side and was absent bilaterally in 12%.

SM Akram Hossain et al[50] (2012) studied 55 adult dry skulls and observed that the dome was present bilaterally, in all the specimens.

Vijisha P et al[57] (2013) in their study of 30 adult dry skulls reported that dome was observed only on right side in 26.6% and only on left side in 3.33 % and bilaterally in 70%.

Shifan Khanday et al[48] (2013) studied 648 JF of 324 skulls and found out that in 20% skulls dome was present bilaterally. It was present unilaterally on the right side in 40% and on the left side in 29%.The dome was absent in 11%.

Rahul Rai et al[41] (2013) studied 100 dry skulls and observed that dome was present bilaterally in 48%, on the right side in 30%, left side in 10%, and absent bilaterally in 12%.

Avanish Kumar et al[5] (2014) in their study of JF of 68 skulls, stated that the dome was observed bilaterally in 57.35%, only on the right side in 29.4%, only on the left side in 8.82% and was absent bilaterally in 4.41%.

Chandni Gupta et al[9] (2014) studied 50 adult dry skulls and reported that dome was present in 74 % on right side and 58% on left side.

Peiris HRD et al[18] (2014) analysed 75 dry skulls and reported that the dome indicating the presence of a jugular bulb was present on right side in 34.9% and left side in 47.6% of skulls.

Roma Patel et al[44] (2014) in their study of 100 dry skulls stated that the jugular bulb dome was present bilaterally in 23%, unilaterally on right side in 30%, left side in 11% and absent bilaterally in 36%.

INCIDENCE OF SEPTATE JUGULAR FORAMEN

Peter.L.Williams and Roger Warwick[38] (1980) in ' Gray's Anatomy' stated that sometimes margins of the notch in which the inferior ganglion of IX cranial nerve is lodged, extend to divide the JF into two or three compartments.

A.S. Breathnack[1] (1948) in **'**Frazer's anatomy of the human skeleton' stated that JF has a larger part laterally for the vein and a smaller part medially for the nerves, these two parts are separated in part or whole by a small bony projection from the occipital bone above the anterior condylar canal, which is called the intrajugular process.

R R Sturrock[40] (1988) in his study of 156 adult dry skulls observed septate right JF in 4.5% and septate left JF in 14.1% specimens.

MT Hatiboglu et al[30] (1991) did a study on 300 Anatolian skulls of 17th & 18th centuries and reported that in 8.2% right JF was septate whereas in 23.9% left was septate.

H.L. Guido et al[19] (1997) studied 100 Brazilian skulls and stated that one septum was present bilaterally in 5%, unilaterally only on the right JF in 7% and only on the left JF in 3% .Tripartite division was present in 6% of right JF and 5% of left JF.

I Tekdemir et al[21] (2001) studied 80 JF of 40 dry skulls and observed 13 (16.25%) bony septa (5 bilateral, 3 unilateral).

MM Patel et al[37] (2007) in their study of 91 skulls stated that JF were septate in 73% on right side and 67.6% on left side.

DR Sawyer et al[10] (2009) studied bridging of JF in 234 skulls and reported septate JF in 8.1%, with the right showing a significantly higher incidence than the left.

Ekinci et al[15] (2009) conducted a study on 70 skulls of Turkish population and reported that bony bridging was observed in 20% of cases and was not in 80%. In addition one tripartite JF was observed.

Hussain Saheb et al[20] (2010) observed that right JF was septate in 66.4% and left JF was septate in 75.2% of 125 adult dry skulls studied.

Pereira et al [17](2010) studied the Jugular Foramina of 111 dry skulls and reported that 83.8% of skulls lacked the septum bilaterally.

Ruchira Sethi et al[45] (2011) analysed 56 adult dry skulls and reported the presence of one septum unilaterally in 17.8% skulls on right side and in 14.3% skulls on left side. They also described a tripartite JF in 10.7% skulls bilaterally.

Namita A Sharma et al[33] (2011) in their study of JF in 50 dry skulls said that complete septation was present in 10% of the skulls and incomplete in 36% skulls.

Anjali Singla et al[4] (2012) studied 50 adult dry skulls and reported that all the specimens had septate JF, septum could be complete or partial.

SM Akram Hossain et al[50] (2012) studied 55 adult dry skulls and observed that JF was septate in 100% of the specimens.

Vijisha P et al[57] (2013) in their study of 30 adult dry skulls reported that JF was septate in 83.3% on right side and 86.6% on left side.

Anitha MR et al[3] (2013) in their study of the Jugular Foramina of 100 adult dry skulls reported that JF was septate in 8% on right side and 11% on left side.

Shifan Khanday et al[48] (2013) analysed 648 JF of 324 skulls and found out that the right JF was septate in 36.3% and left JF in 24.1%.

Rahul Rai et al[41] (2013) studied 100 dry skulls and observed that the JF were septate in all specimens.

Avanish Kumar et al[5] (2014) in their study of JF of 68 skulls, stated that a single septum was present in all the JF.

Chandni Gupta et al[9] (2014) studied 50 adult dry skulls and reported that all the specimens had a septate JF, the septum could be complete or incomplete.

Peiris HRD et al[18] (2014) analysed 75 dry skulls and reported that 84.7% of the left JF and 80.6% of the right JF were septate.

Roma Patel et al[44] (2014) in their study of 100 dry skulls stated that 45% of the JF on right side and 39% on left side were septate.

N. Himabindu et al[32] (2015) analysed the JF of 110 adult dry skulls and reported that absence of septation on right was in 16.70% and left in 18.70% of the specimens.

TRIPARTITE JUGULAR FORAMEN

Peter.L.Williams and Roger Warwick[38] (1980) in their book stated that sometimes margins of the notch in which the inferior ganglion of IX cranial nerve is lodged, extend to divide the JF into two or three compartments.

T.H Bryce[54] (1915) in 'Quain's Elements of Anatomy' described the JF as being divided into three compartments by two marked constrictions; the lateral one transmits the IJV, the middle transmits the glossopharyngeal, vagus & spinal accessory nerves; and the most anterior one, sometimes completely separated by a spicule of bone (the intrajugular process) transmits the inferior petrosal sinus.

MT Hatiboglu et al[30] (1991) did a study on 300 Anatolian skulls of 17th and 18th centuries and reported that the inferior petrosal sinus occasionally passed through a small separate opening in JF. The occurrence of this small separate opening was seen on the right in 5.6% and on the left in 4.6%.

H.L. Guido et al[19] (1997) studied 100 Brazilian skulls and stated that JF was tripartite on the right side in 6% and left side in 5%.

I Tekdemir et al[21] (2001) studied 80 JF of 40 dry skulls and reported that in one specimen (1.25%) the JF was divided anatomically into three parts.

Ekinci et al[15] (2009) conducted a study on 140 JF in 70 skulls of Turkish population and reported the presence of one tripartite JF (0.71%).

Ruchira Sethi et al[45] (2011) analysed 56 adult dry skulls and reported the presence of tripartite JF in 10.7% skulls bilaterally.

Anjali Singla et al[4] (2012) studied 50 adult dry skulls and reported 6% of specimens to have tripartite JF bilaterally.

Shifan Khanday et al[48] (2013) analysed 324 skulls and found out that 0.61% had tripartite JF bilaterally.

TYPE OF SEPTUM IN JUGULAR FORAMEN

J.C Brash and E.B.Jamieson[25] (1937) in 'Cunningham's textbook of anatomy' stated that in some skulls a curved process, called intrajugular process projects from the floor of jugular notch of the occipital bone and partially or completely subdivides the JF. Sometimes spicules of bone project across the foramen from its petrosal and occipital margins, and may divide the same into compartments.

A.S. Breathnack[1] (1948) in **'**Frazer's anatomy of the human skeleton' wrote that JF is divided by an intrajugular process of bone from either or both the occipital and temporal sides.

T.H Bryce[54] (1915) in 'Quain's Elements of Anatomy' stated that at the forepart of jugular notch of the jugular process of occipital bone, a small projection is frequently present, called the intrajugular process. Occasionally it is prolonged into a spicule of bone, which meets the petrosal part of temporal bone.

Y. Dodo[62] (1986) studied anatomical nature and pattern of incidence of bony bridging of JF using 64 foetal crania of age nine months to term and 222 adult crania of Japanese population. In addition, the region of JF of an adult cadaver was dissected to clarify the relationship between the cranial nerves passing through and the

intrajugular processes of JF. The observations were: (1) Intrajugular process of the temporal bone is situated posterior to the triangular depression of petrous part of the bone. (2) Bony bridging of JF is established by the contact of intrajugular process of temporal bone with bony process of occipital bone projecting either from just above the anterior condylar canal (Type I) or from posterior to the anterior condylar canal (Type II). (3) If both the processes of occipital bone reach the intrajugular process of temporal bone simultaneously, JF is divided into 3 compartments. (4) In the case of Type I bridging, the anteromedial compartment transmits the IX cranial nerve, while the posterolateral compartment gives passage to X nerve, XI nerve and IJV. (5) In the case of Type II bridging, the anteromedial compartment contains the glossopharyngeal, vagus and accessory nerves, and the posterolateral compartment transmits IJV. (6) When tripartite division of JF occurs, the anteromedial compartment transmits the IX nerve, the middle compartment contains the X and XI nerves, and the posterolateral compartment transmits IJV.

R R Sturrock[40] (1988) studied 156 adult dry skulls and observed that right JF had one complete septum in 3.2% and one incomplete septum in 1.3% whereas left JF had one complete septum in 3.2% and

one incomplete septum in 10.9% specimens. He also stated that the incomplete septa in life were probably completed by cartilage.

MT Hatiboglu et al[30] (1991) studied 300 Anatolian skulls of 17th and 18th centuries and reported that complete septum (intrajugular process) was present in 5.6% of right JF and 4.3% of left JF. Incomplete or partial septum was observed in 2.6% of right and 19.6% of left JF. The JF had two septa in 5.6% on right and 4.6% on left side.

A.L.Rhoton Jr et al[2] (2000) described that the junction of petrosal and sigmoid parts of JF is the site of bony prominences on the opposing surfaces of temporal and occipital bones. These are called the intrajugular processes, which are joined by a fibrous or less frequently an osseous bridge, the intrajugular septum. This separates the sigmoid and petrosal parts of JF. The IX, X and IX cranial nerves are related to the medial margin of the intrajugular process of temporal bone.

OE Idowu[34] (2004) studied 40 JF of 20 Nigerian skulls and stated that a bony bridge completely partitioned the JF in 3 (7.5%) of the JF.

MM Patel et al[37] (2007) in their study of 91 skulls stated that partial septum was observed in about 50% of the skulls on right side and 50% on left side whereas complete septum was observed in around 23% on right side and 17.6% on left side.

J. Linn et al[23] (2009) in their MRI study stated that intraforaminal compartments could be identified by depicting the temporal and occipital intrajugular processes as well as the dural septum separating petrosal from sigmoid portion.

Keles B et al[27] (2009) studied JF anatomy by microscopic dissection of 22 cadaveric head specimens and observed the presence of a complete bony septum bilaterally in 13.6% specimens.

Hussain Saheb et al[20] (2010) studied 125 adult dry skulls and observed that one complete septum was present in 20.8% on right side and 16.8% on left side. One incomplete septum was present in 45.6% on right side and 58.4% on left side.

Pereira et al[17] (2010) studied 111 dry skulls and reported that 0.9% showed a complete septum bilaterally and 0.9% showed incomplete septum bilaterally, 14.4% had unilateral septate JF.

Ketu Chauhan et al[28] (2011) in their study of 50 dry skulls reported that JF was partitioned by a complete septum in 6% and 8% of specimens on right and left sides respectively.

Ruchira Sethi et al[45] (2011) analysed 56 adult dry skulls and reported that of the 17.8% septate right JF, 7.1% had partial septum and

of the 14.3% septate left JF, 4.3% had partial septum. They also described a tripartite JF in 10.7% skulls bilaterally. They reported that incomplete or partial septa were never observed bilaterally.

Namita A Sharma et al[33] (2011) in their study of 50 dry skulls said that complete septation was present in 10% skulls, in which 6% was bilateral. It was present unilaterally on right side in 2% and 2% on left side. Partial septation was present totally in 36% with incidence bilaterally in 18%, unilaterally on right side in 4% and left side in 14 %.

Anjali Singla et al[4] (2012) studied 50 adult dry skulls and reported that bilaterally one complete septum was present in 4% and two complete septa in 6%. Unilaterally 4% had one complete septum on right side. The remaining specimens had a partial septum.

SM Akram Hossain et al[50] (2012) studied 55 adult dry skulls and observed that septum was complete on right side in 76.36% and left side in 90.91% while incomplete on right side in 23.64% and left side in 9.09%.

Vijisha P et al[57] (2013) in their study of 30 adult dry skulls reported that right JF had complete septum in 10% and incomplete septum in 73.3 %. Left JF had complete septum in 6.6 % and incomplete septum in 80 %.

Rahul Rai et al[41] (2013) studied 100 dry skulls and observed that septum was complete on right side in 68% and on left side in 21% whereas incomplete on right side in 32% and on left side in 79%.

Shifan Khanday et al[48] (2013) studied 648 JF of 324 skulls and found out that 12.6% of right JF and 12.8% of left JF had one complete septum. One partial septum was noticed in 23.7% of right JF and 11.3% of left JF.

Avanish Kumar et al[5] (2014) in their study of JF of 68 skulls, stated that complete septum was present in 16.18% and 8.80%, and incomplete septum in 83.82% and 91.2% on right and left sides respectively.

Chandni Gupta et al[9] (2014) studied 50 adult dry skulls and reported that one complete septum was present in 44% on right side and 42% on left side whereas the rest of the specimens had one incomplete or partial septum.

Ivan Jovanovic et al[22] (2014) in their study of 37 sagittal sections of adult dried human skulls reported that one complete septum was present in 32% of specimens.

Peiris HRD et al[18] (2014) analysed 75 dry skulls and reported that one complete septum was observed in 14.7% of left JF and 10.6% of right JF and partial septum was noticed bilaterally in 70% of skulls.

Roma Patel et al[44] (2014) in their study of 100 dry skulls stated that complete septum was present in 16% on right side and 14% on left side. Partial septation of JF was present in 29% of skulls on right side and in 25% on left side.

N. Himabindu et al[32] (2015) analysed the JF of 110 adult dry skulls and reported that complete septum was seen on right side in 22% and on the left in 27.5% while incomplete bony septum was found on the right in 33% and on the left in 30% of skulls.

PRESENCE OF ACCESSORY OPENING IN THE WALLS OF JUGULAR FORAMEN

Ruchira Sethi et al[45] (2011) analysed 56 adult dry skulls and observed that in 3.6% skulls, an additional accessory foramen was observed in the posteromedial wall of JF, on left side only.

SITE WHERE THE ACCESSORY OPENING LEADS TO.

Ruchira Sethi et al[45] (2011) analysed 56 adult dry skulls and reported that the additional foramen observed in 3.6% of skulls was communicating with posterior condylar canal, as observed by passing a thin probe through it.

Embryology

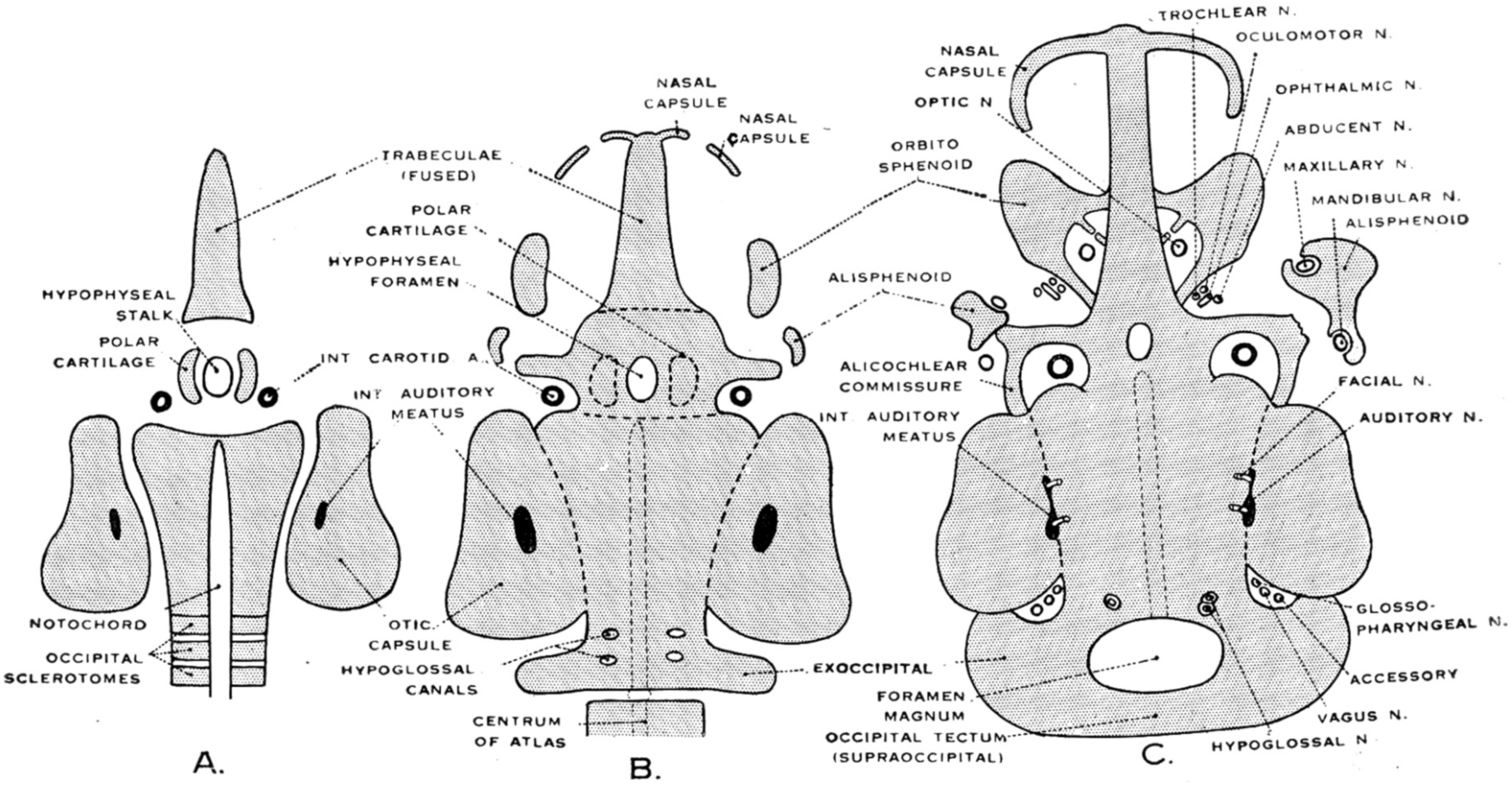


Fig.4 : Three stages in the development of neural portions of chondrocranium.

Right side in C is a later stage than left side.[59]

EMBRYOLOGY

Skull consists of the neurocranium, which is the protective case around the brain and the viscerocranium or splanchnocranium which makes up the jaw skeleton.[59] The blastemal skull or desmocranium begins to appear at the end of the first month of development of the embryo as localised masses formed by condensation and thickening of the mesenchyme surrounding cerebral vesicles. Chondrocranium is that part of neurocranium which passes through or remains in cartilage. The membranous neurocranium, consists of dermal bones and corresponds to the cranial vault, and it is not preformed in cartilage.[38,52]

The first mass of desmocranium is the occipital plate or parachordal cartilage derived from the central regions of all four occipital sclerotomes. It appears in the occipital region surrounding the notochord and outlines the basiocciput. Two lateral extensions grow from the occipital plate, which form the exoccipital components. These are derived from sclerotomes 3 and 4. Simultaneously the mesenchymal condensation extends anteriorly, dorsal to pharynx and reaches the primordium of hypophysis and thus clivus and dorsum sellae of the future sphenoid bone are established.

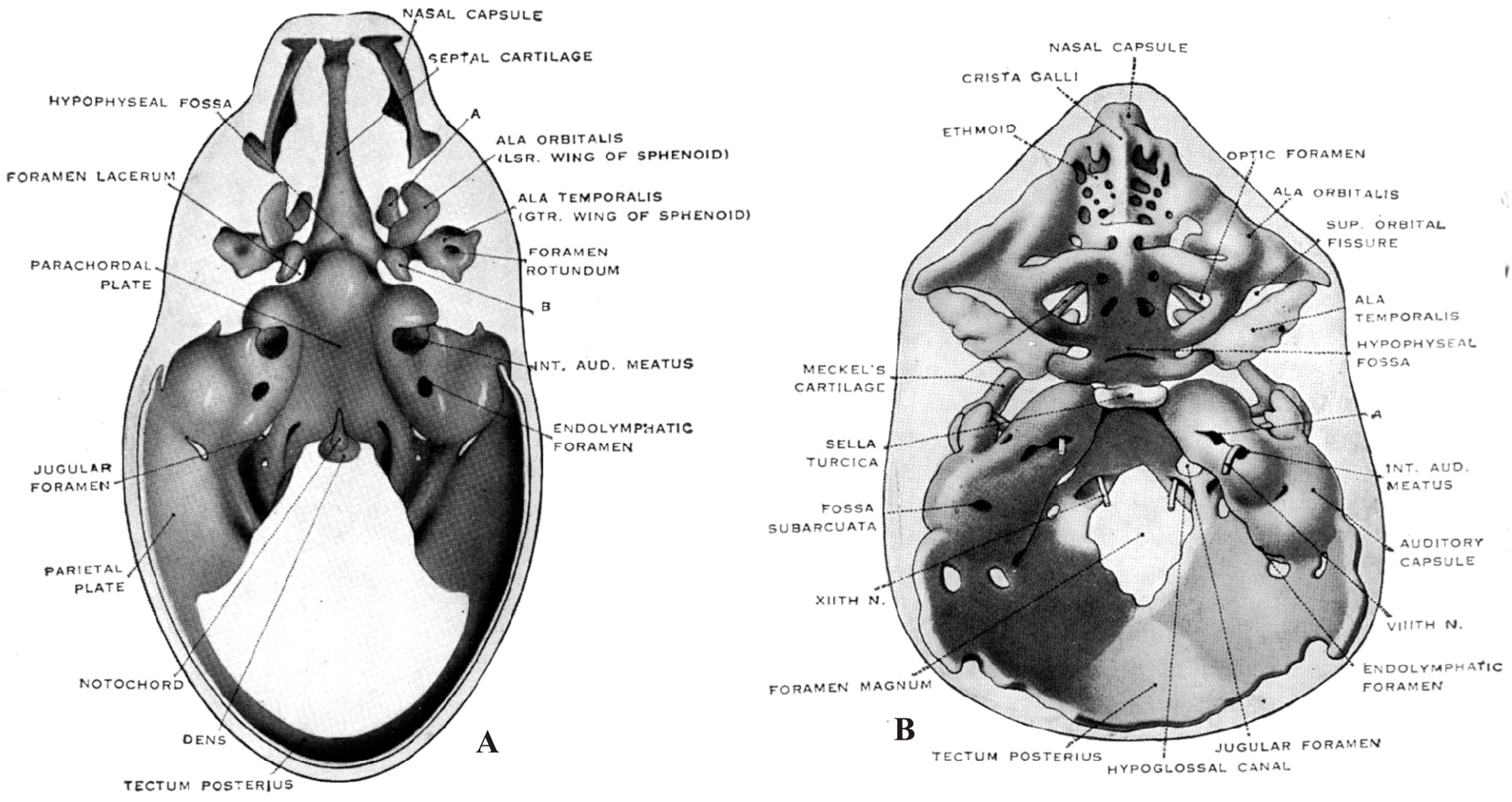


Fig.5 Dorsal aspect of a model of the chondrocranium.[59]

A - 20mm human embryo. B - 80mm human foetus

During the 5th week of development, one otic capsule appear on each side as mesenchymal condensation around each otocyst. Each otic capsule lies lateral to the parachordal cartilage and later on fuses with the lateral process of the same. However this fusion is incomplete, leaving behind a wide hiatus through which the internal jugular vein, glossopharyngeal nerve, vagus nerve and accessory nerve pass. This foramen left between the posterior extremity of otic capsule and the parachordal cartilage is the Jugular Foramen, [38,52,59] also called foramen lacerum posterius.[42] (Fig. 4&5)

Materials and Methods

MATERIALS AND METHODS

STUDY MATERIALS:

- 100 human adult dry skulls of unknown sex
- Digital Vernier Caliper
- Flexible wire
- 25G Spinal needle and rubber stopper

STUDY METHOD:

Dry skull Method

SPECIMEN COLLECTION:

Hundred human adult dry skulls of unknown sex available in the Institute of Anatomy, Madras Medical College were used for this study.

INCLUSION CRITERIA:

1. Adult human dry skulls of unknown sex.
2. Third molar tooth erupted.
3. Well defined skull sutures.

EXCLUSION CRITERION:

Damaged skulls with unidentifiable features of Jugular Foramen

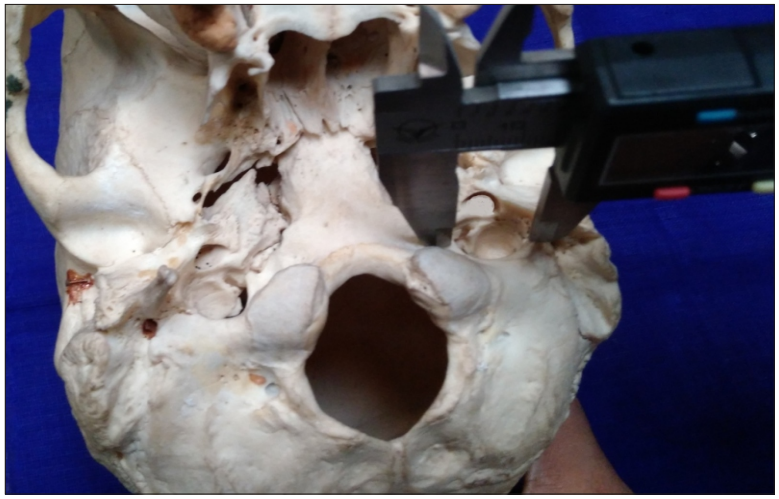


Fig.6: Mediolateral diameter of Jugular Foramen

Fig.7: Anteroposterior diameter of Jugular Foramen

Fig.8: a - Mediolateral diameter of right JF
b - Mediolateral diameter of left JF
c - Anteroposterior diameter of right JF
d - Anterposterior diameter of left JF

The following measurements were made with the use of digital Vernier caliper with a precision of 0.1 mm.

1. **Maximum mediolateral diameter of Jugular Foramen:** The distance between the medial most and lateral most points of the Jugular Foramen. This corresponds to the length of the Jugular Foramen. (Fig. 6)

2. **Maximum anteroposterior diameter of Jugular Foramen:** The distance between the anterior most and posterior most points of the Jugular Foramen. This corresponds to the breadth of the Jugular Foramen. (Fig.7)

3. **Area of Jugular Foramen:** Derived as the length of Jugular foramen multiplied by the breadth of Jugular Foramen.

4. **Side dominance of Jugular Foramen:** Identified by comparison of the area of right and left Jugular Foramina of the same skull.

   Right sided dominance- Area of right JF more than area of the left JF

   Left sided dominance- Area of left JF more than area of the right JF

   No side dominance- Area of the right JF equal to area of left JF

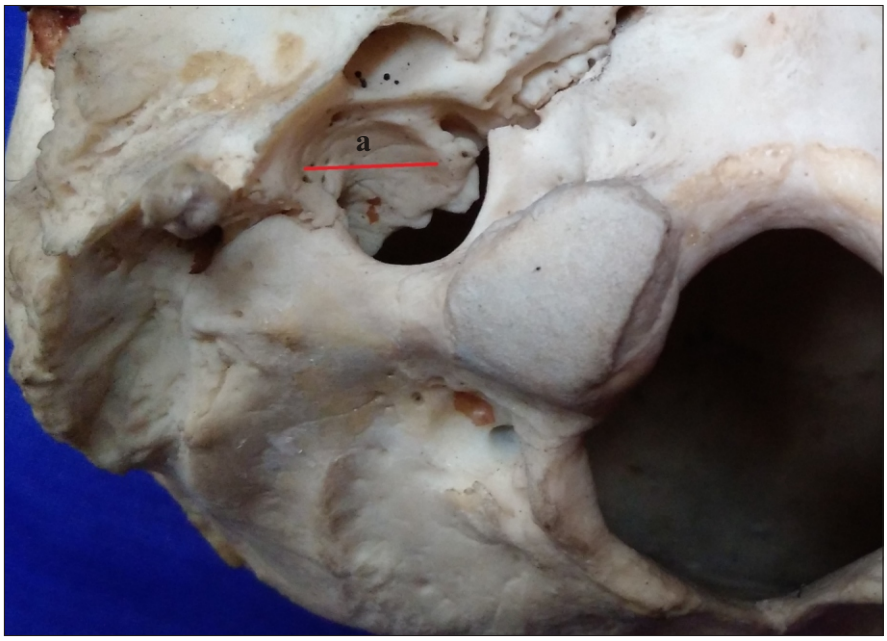


Fig.9 : a - Width of Jugular Fossa

Fig.10 : Width of Jugular Fossa measured using digital vernier caliper

P- Posterior A-Anterior

5. **Width of Jugular Fossa:** The maximum diameter of jugular fossa measured as the distance between lateral most and medial most points in the Jugular Fossa.(Fig.9&10)

6. **Depth of Jugular Fossa:** Measured as the distance between the deepest point in the Jugular Fossa/summit of dome, if domed roof is present (point A) and a vertically corresponding point on the inferior border of the jugular fossa (point B) using a 25G spinal needle and a rubber stopper. The reading is taken on a digital Vernier caliper. (Fig.11,12&13)

The following morphological parameters were observed by naked eye examination.

7. **Presence of domed Jugular Fossa:** Analysed by the presence of domed bony roof of Jugular Fossa.(Fig.14)

8. **Presence of septum in the Jugular Foramen:** Analysed by the presence of bony bridge(septum) dividing the Jugular Foramen into compartments(Fig.15).The Jugular Foramen is classified as follows:

   Bipartite Jugular Foramen- presence of one septum

   Tripartite Jugular Foramen- presence of two septa

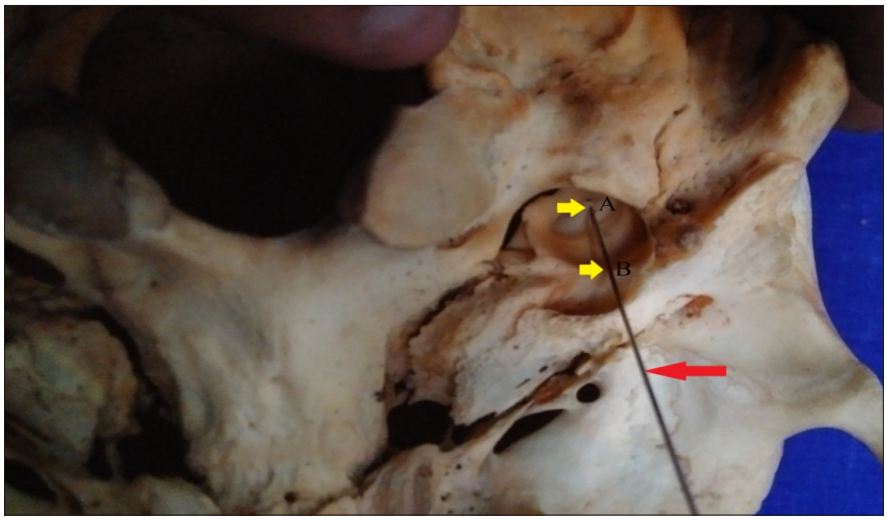


Fig.11 : ➔ Needle measuring the depth of Jugular Fossa from point A to point B (marked with yellow arrows)

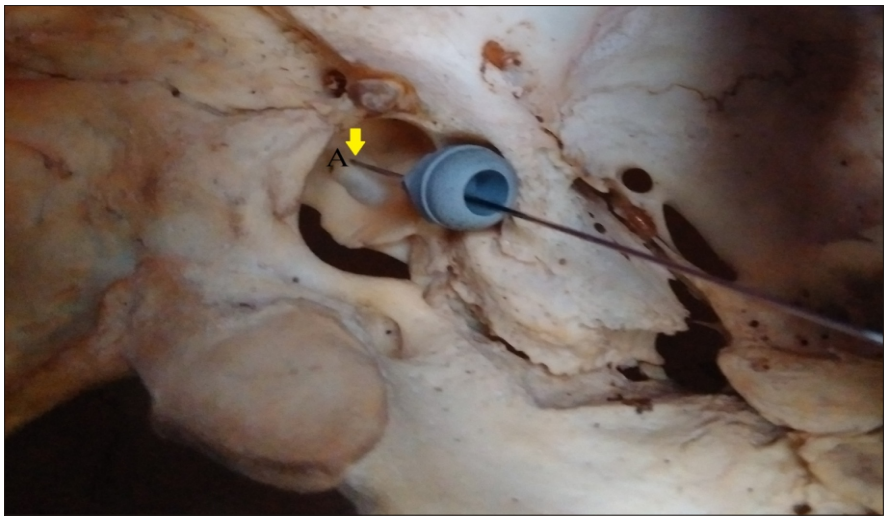


Fig.12 : Point B located with a stopper on the needle.

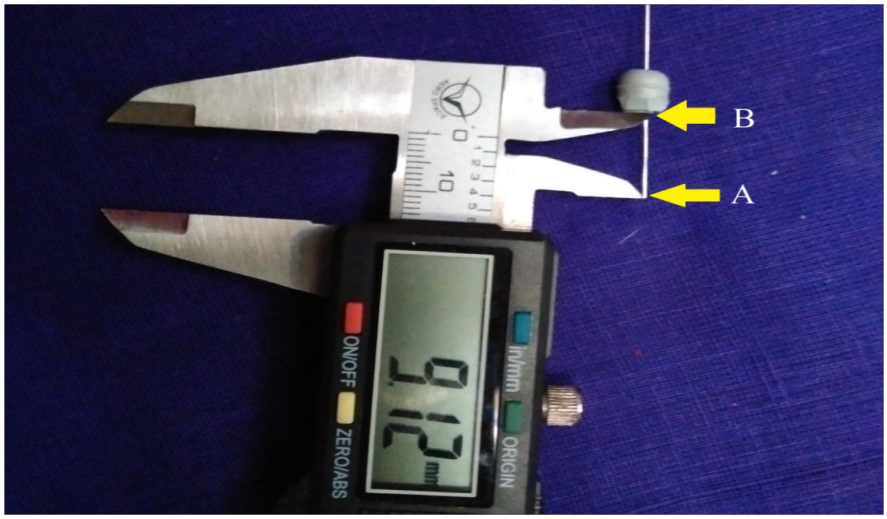
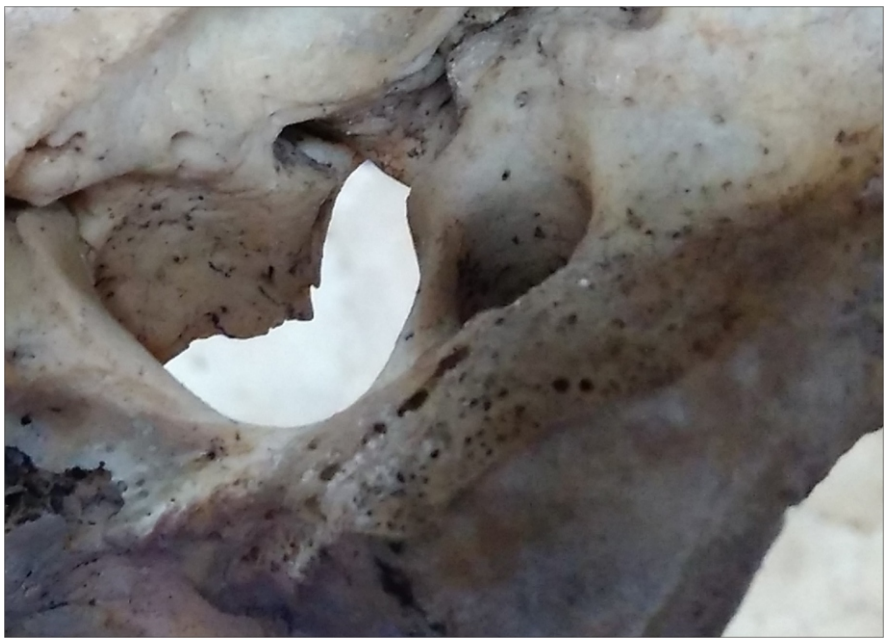
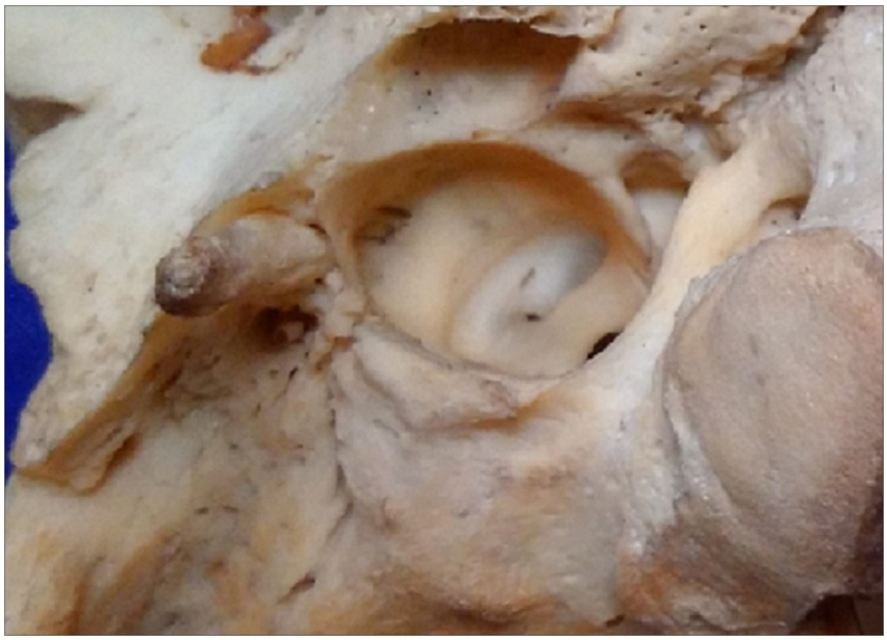


Fig.13 : Depth of Jugular Fossa, reading taken using a digital Vernier Caliper

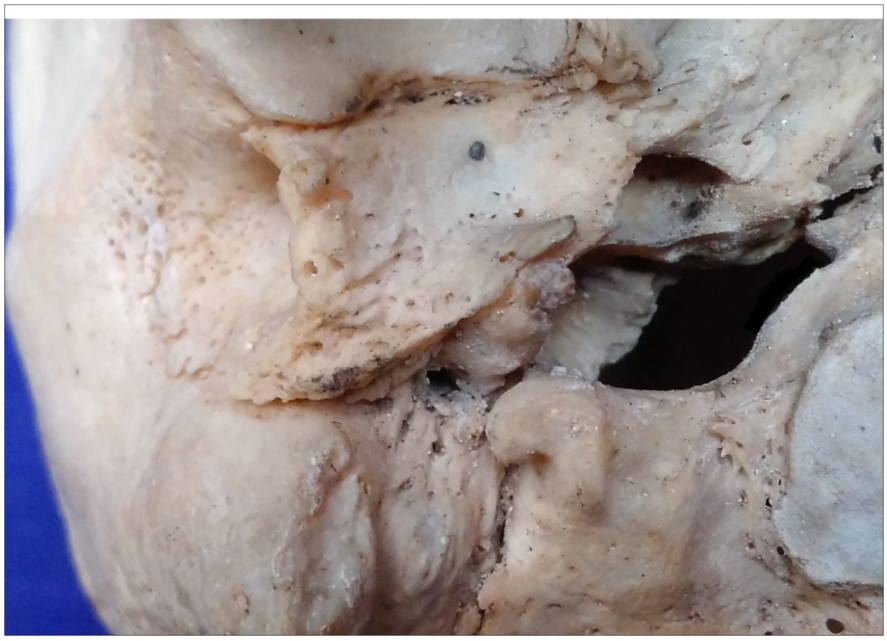


(A) Dome absent

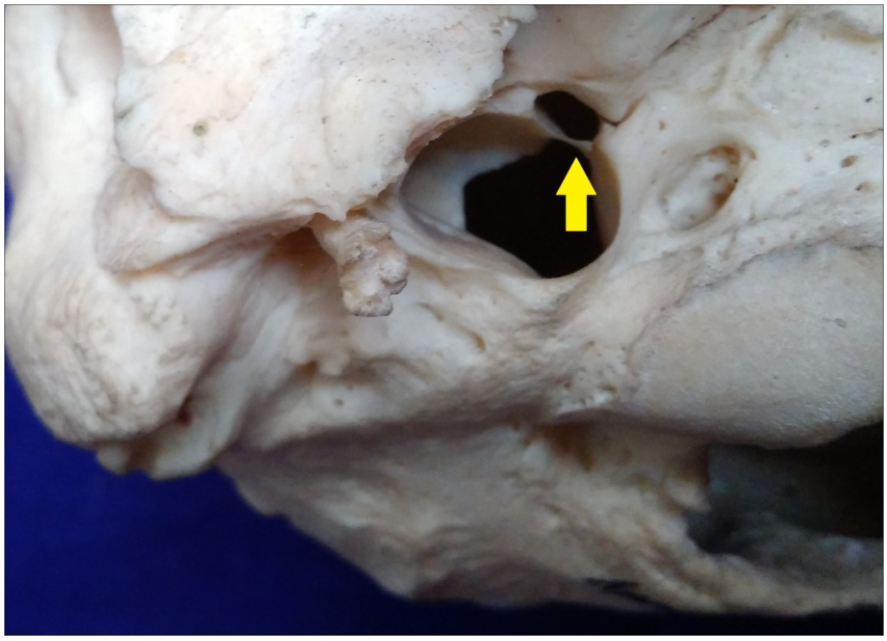


(B) Dome present

Fig.14 : Presence of domed bony roof of Jugular Fossa

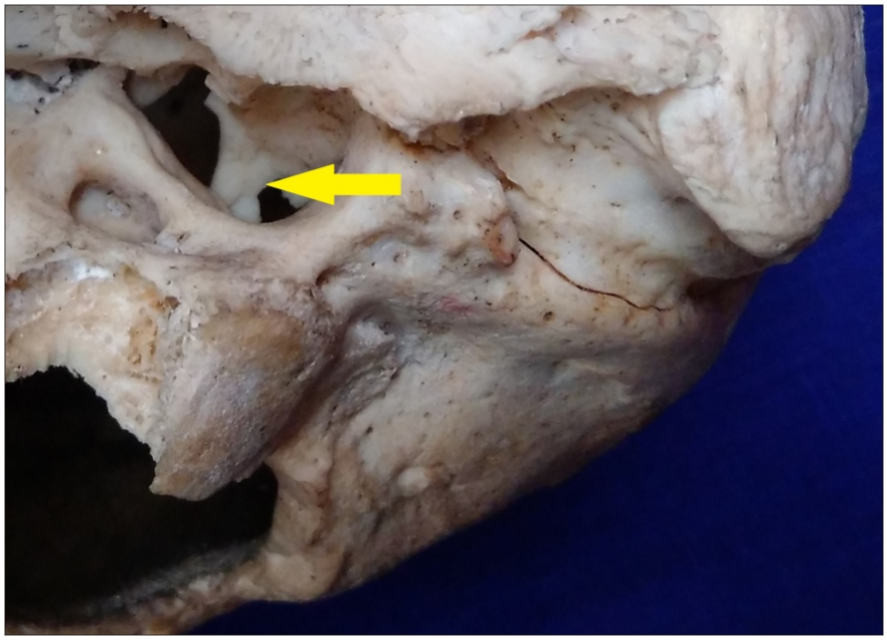


(A) Septum absent

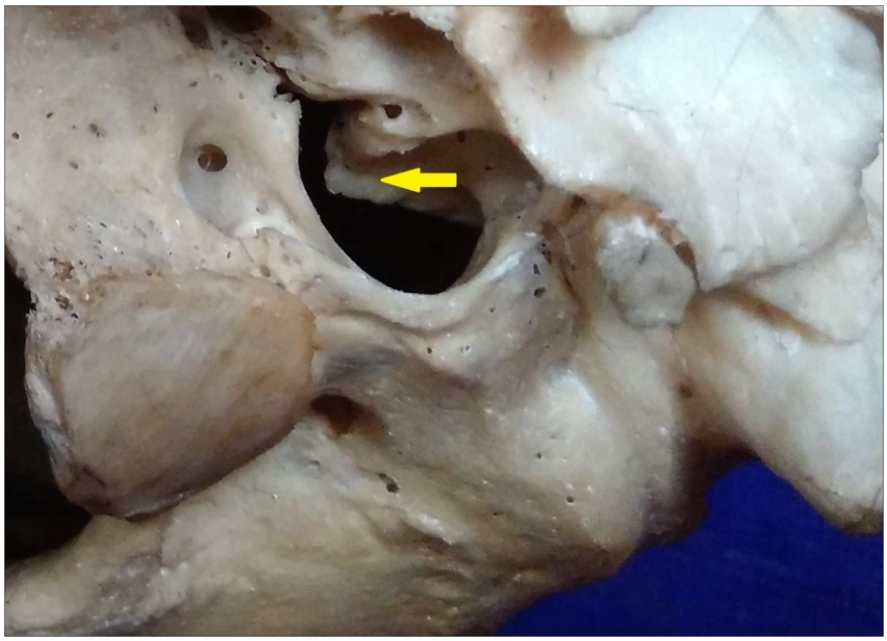


(B) ➔ Septum

Fig.15 : Presence of septum in the Jugular Foramen



(A) Complete septum



(B) Incomplete septum

Fig.16 : Type of septum

9. **Type of septum in the Jugular Foramen:** The nature of the bony bridges is described as whether complete or incomplete. (Fig.16) A complete septum extends from the upper border of the jugular fossa of the petrous temporal bone to the jugular process of the occipital bone and completely divides the foramen.(Fig.17) Incomplete septum is shorter and divides the foramen only partially.(Fig.18)

10. **Presence of accessory opening in the walls of Jugular Foramen:** Any opening in the walls of the Jugular Foramen other than that of mastoid canaliculus is considered as accessory opening.(Fig.19)

11. **Site where the accessory opening leads to.** The canal which opens at the accessory opening is identified by probing the latter with a flexible wire.

All the parameters were analysed at the base of skull, bilaterally. The mean, standard deviation (SD) and range of each dimension and derived index were computed. Differences between right and left sides were analysed for statistical significance by comparing using paired t-test. A probability (p value) of less than 0.05 was considered statistically significant. The association between continuous variables was investigated by means of correlation coefficient.

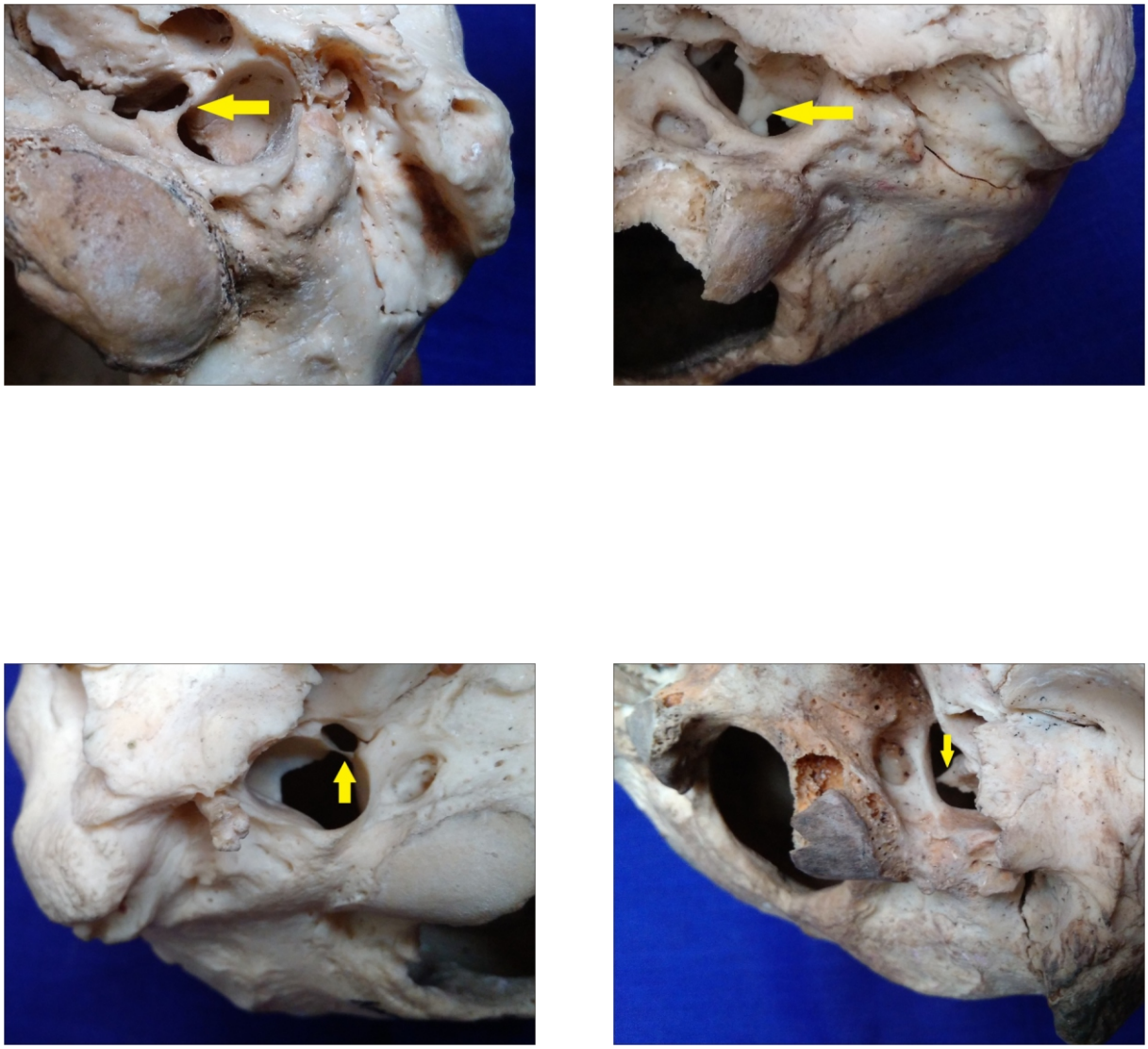


Fig. 17 : Complete septum

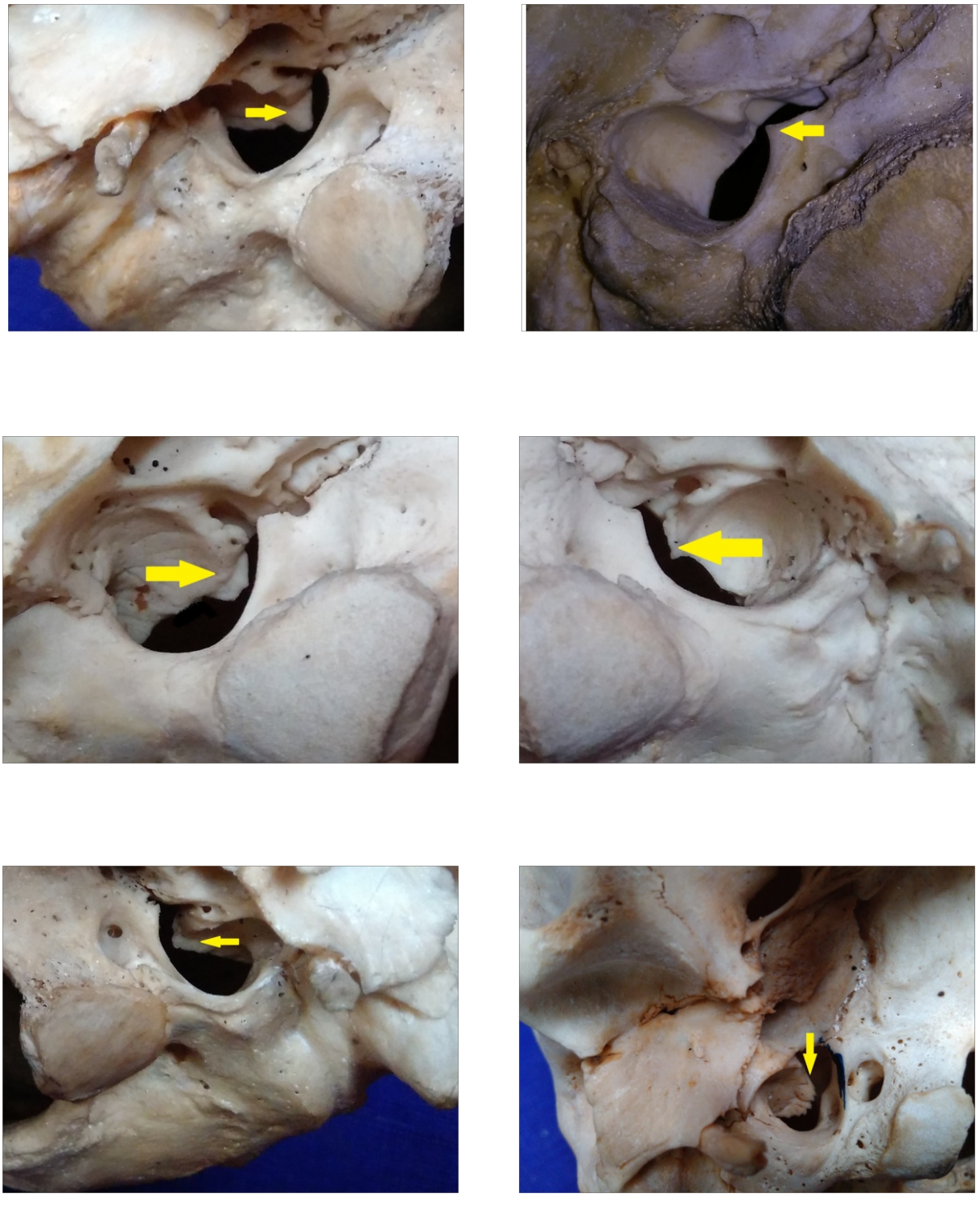
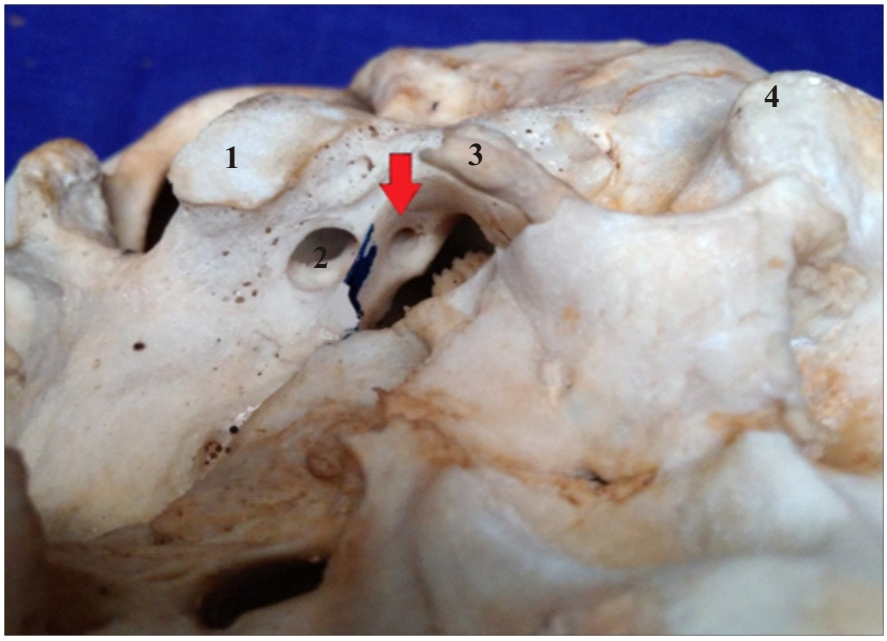


Fig. 18 : Incomplete septum



1- occipital condyle 2 - anterior condylar canal opening
3 - styloid process 4 - mastoid process

Fig. 19 : Accessory opening in the wall of Jugular Foramen

Observation

OBSERVATIONS

The morphometric and morphological parameters were studied on the right and left sides in the Jugular Foramina of 100 adult dry human skulls and observations recorded.

TABLE 1-MEDIOLATERAL DIAMETER OF RIGHT JUGULAR FORAMEN (Rt MLD)

STATISTICAL DATA	Rt MLD in mm
No. of skulls	100
Minimum	9.24
Maximum	20.06
Range	10.82
Mean	14.87
Standard Deviation	2.47

The whole range of values is shown in the histogram below

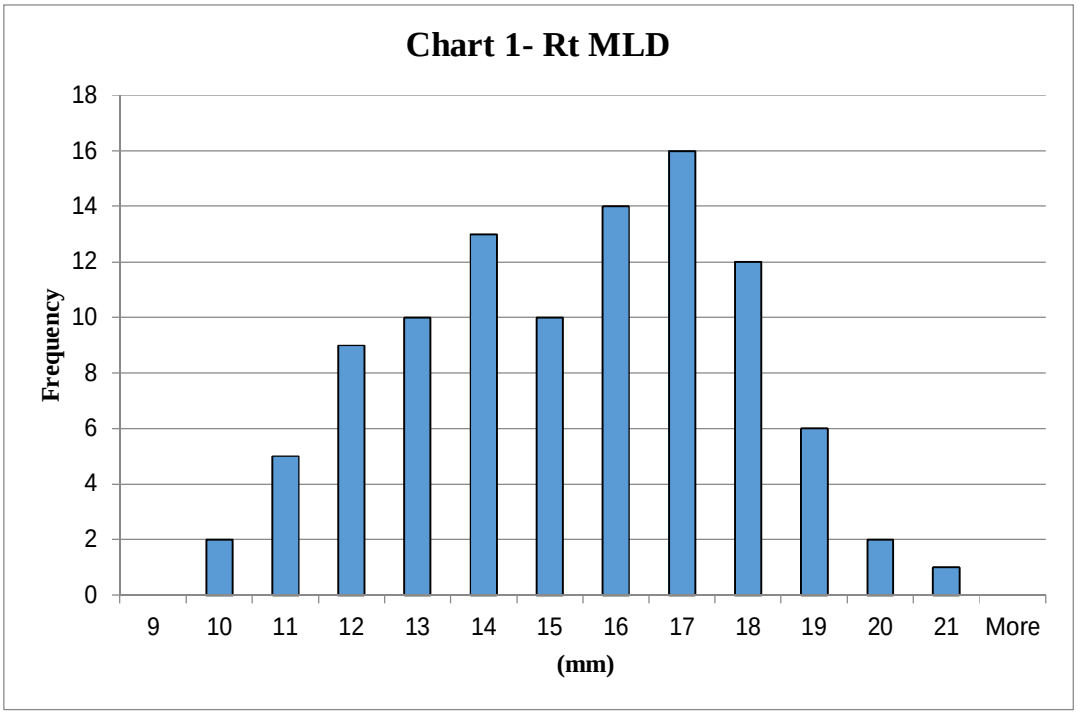


TABLE 2-MEDIOLATERAL DIAMETER OF LEFT JUGULAR FORAMEN (Lt MLD)

STATISTICAL DATA	Lt MLD in mm
No. of skulls	100
Minimum	8.34
Maximum	19.68
Range	11.34
Mean	13.76
Standard Deviation	2.37

The whole range of values is shown in the histogram below

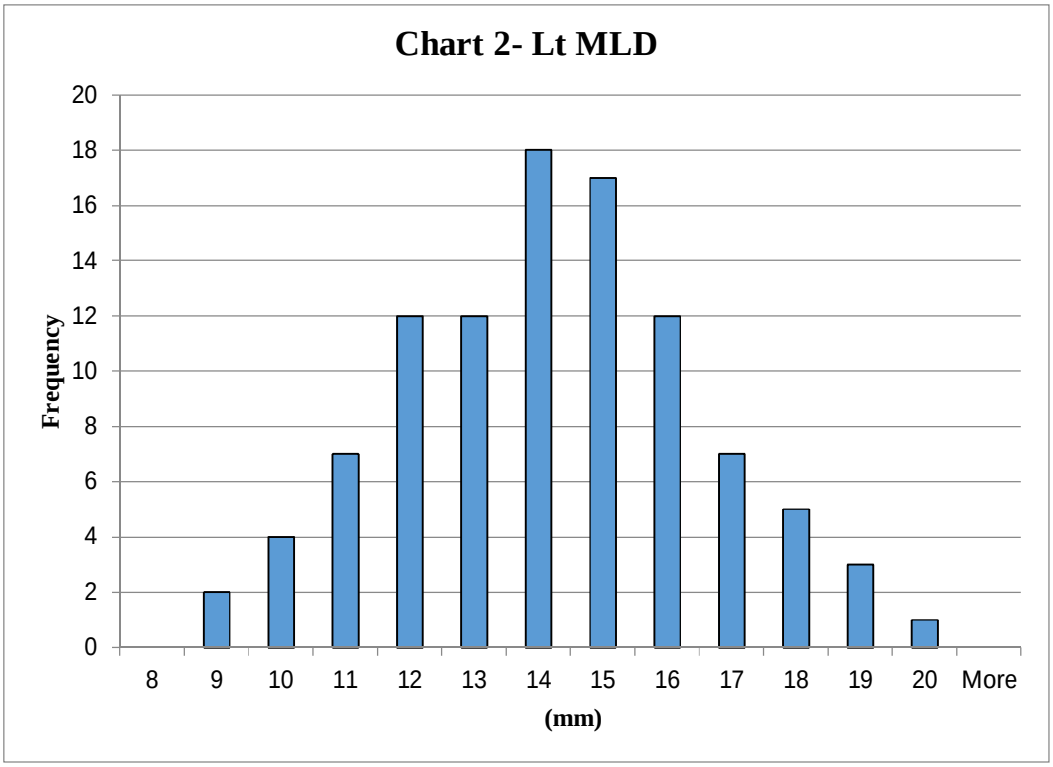


TABLE 3-ANTEROPOSTERIOR DIAMETER OF RIGHT JUGULAR FORAMEN (Rt APD).

STATISTICAL DATA	Rt APD in mm
No. of skulls	100
Minimum	7.59
Maximum	15.89
Range	8.3
Mean	11.90
Standard Deviation	1.93

The whole range of values is shown in the histogram below

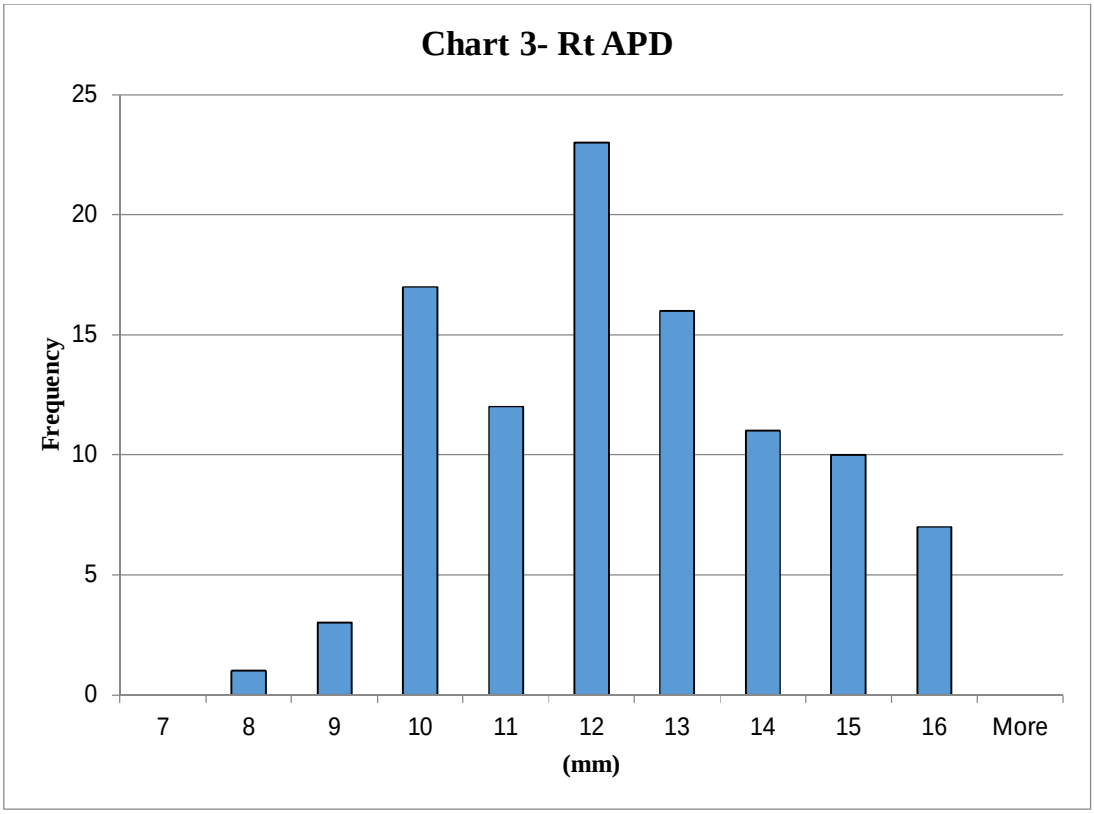


TABLE 4-ANTEROPOSTERIOR DIAMETER OF LEFT JUGULAR FORAMEN (Lt APD)

STATISTICAL DATA	Lt APD in mm
No. of skulls	100
Minimum	7.29
Maximum	15.23
Range	7.94
Mean	10.88
Standard Deviation	1.82

The whole range of values is shown in the histogram below

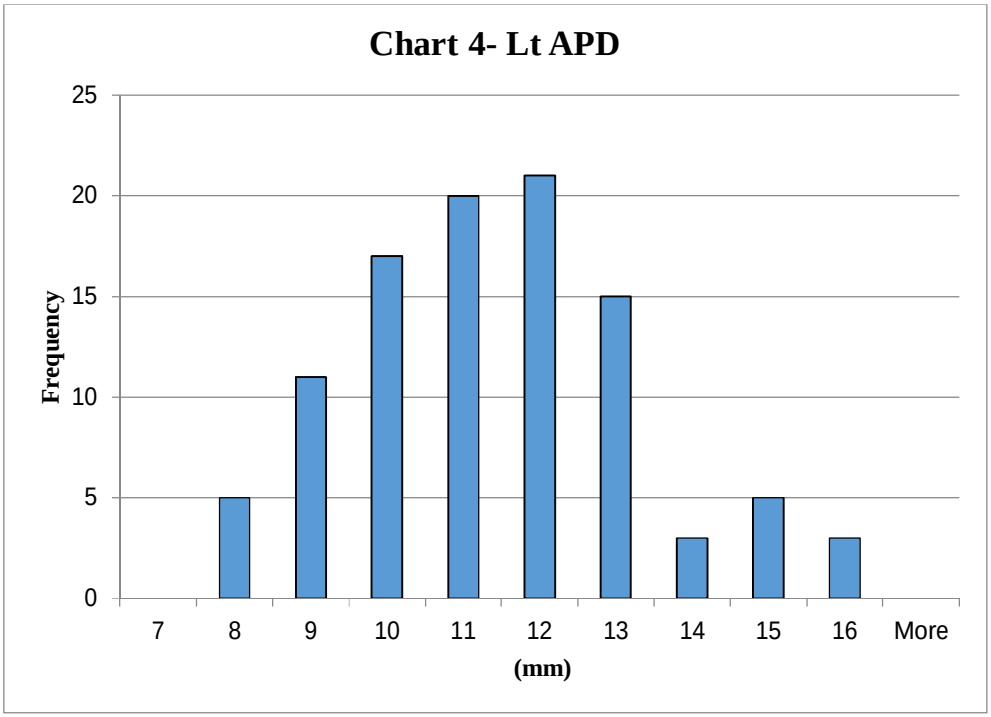


TABLE 5-AREA OF RIGHT JUGULAR FORAMEN (Rt AJF)

STATISTICAL DATA	Rt AJF in mm^2
No. of skulls	100
Minimum	70.13
Maximum	305.41
Range	235.28
Mean	179.23
Standard Deviation	49.39

The whole range of values is shown in the histogram below

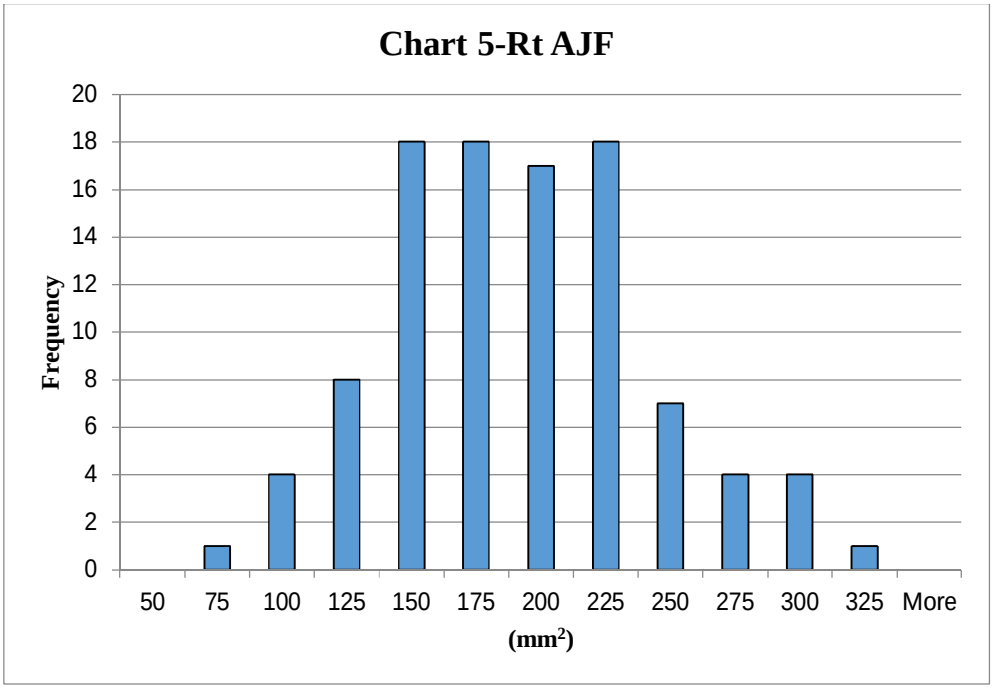
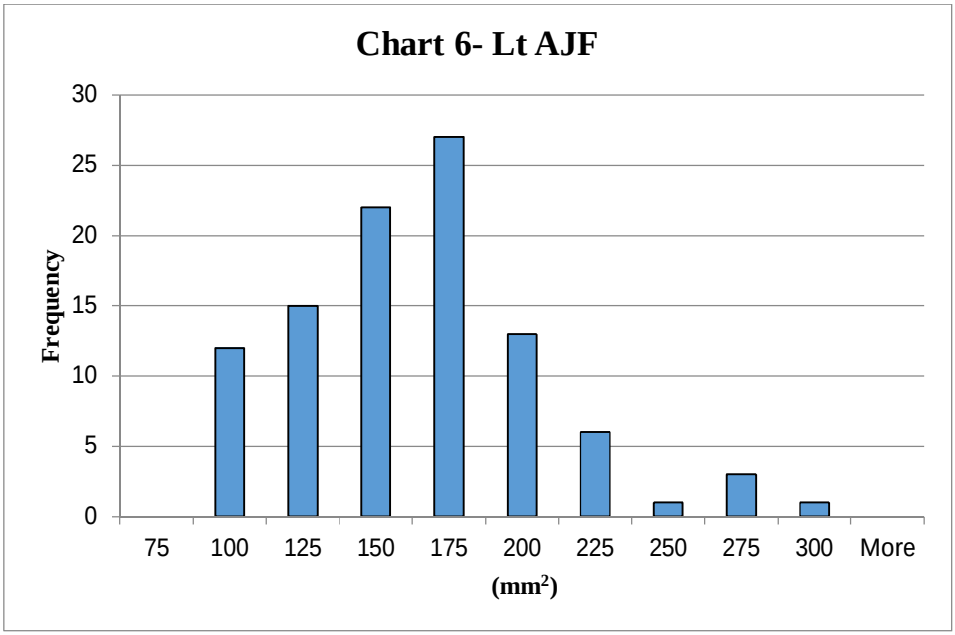
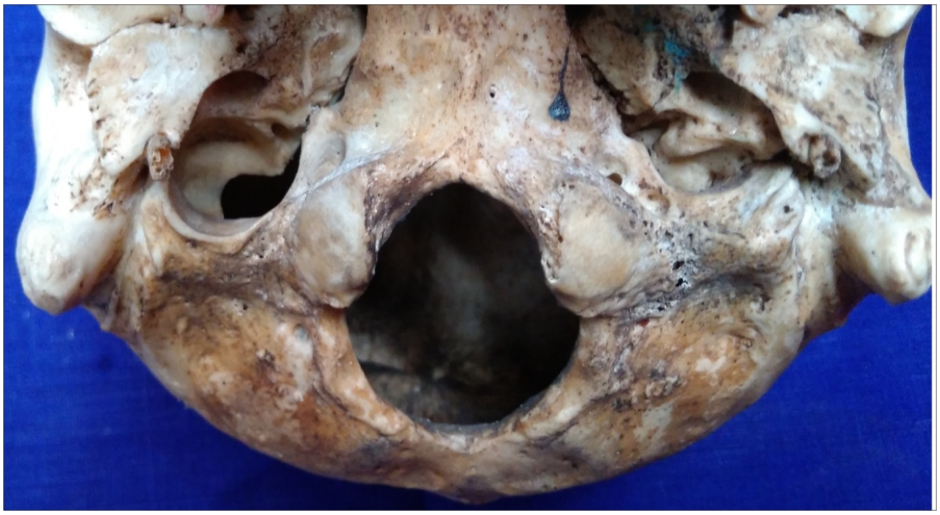


TABLE 6-AREA OF LEFT JUGULAR FORAMEN (Lt AJF)

STATISTICAL DATA	Lt AJF in mm^2
No. of skulls	100
Minimum	78.38
Maximum	294.81
Range	216.43
Mean	151.65
Standard Deviation	43.58

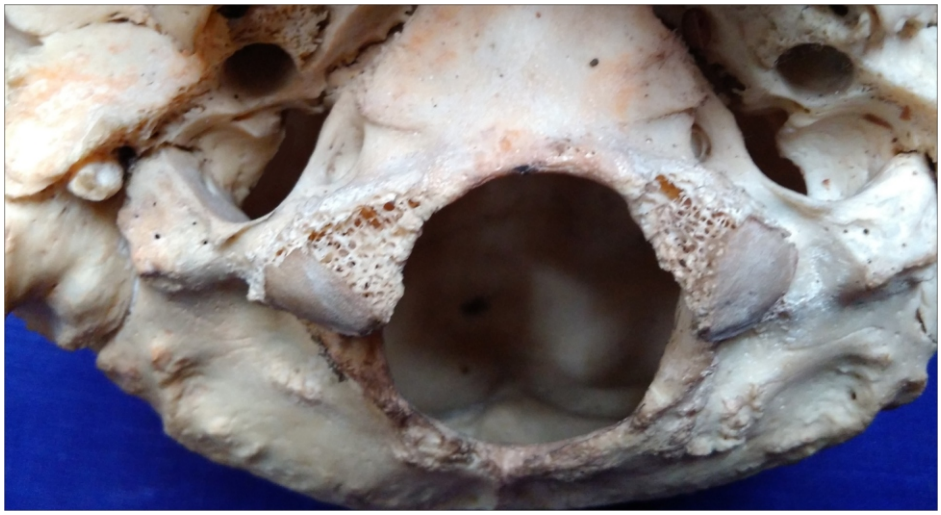
The whole range of values is shown in the histogram below





(A) - Right sided dominance

(B) - Left sided dominance



(C) - No side dominance

Fig.20 : Side dominance of Jugular Foramen

SIDE DOMINANCE OF JUGULAR FORAMEN – Table 7& Fig.20.

Size	Right dominance	Left dominance	No dominance
Number	69	25	6
Percentage	69%	25%	6%

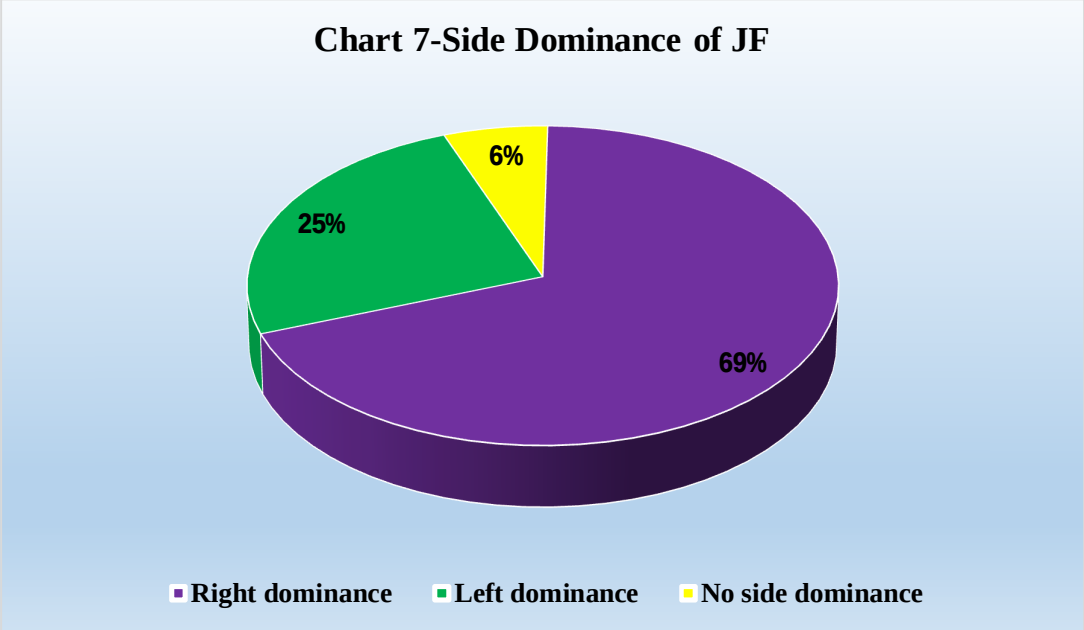


TABLE 8-WIDTH OF RIGHT JUGULAR FOSSA (Rt FJW)

STATISTICAL DATA	Rt FJW in mm
No. of skulls	100
Minimum	5.02
Maximum	13.34
Range	8.32
Mean	7.90
Standard Deviation	1.80

The whole range of values is shown in the histogram below

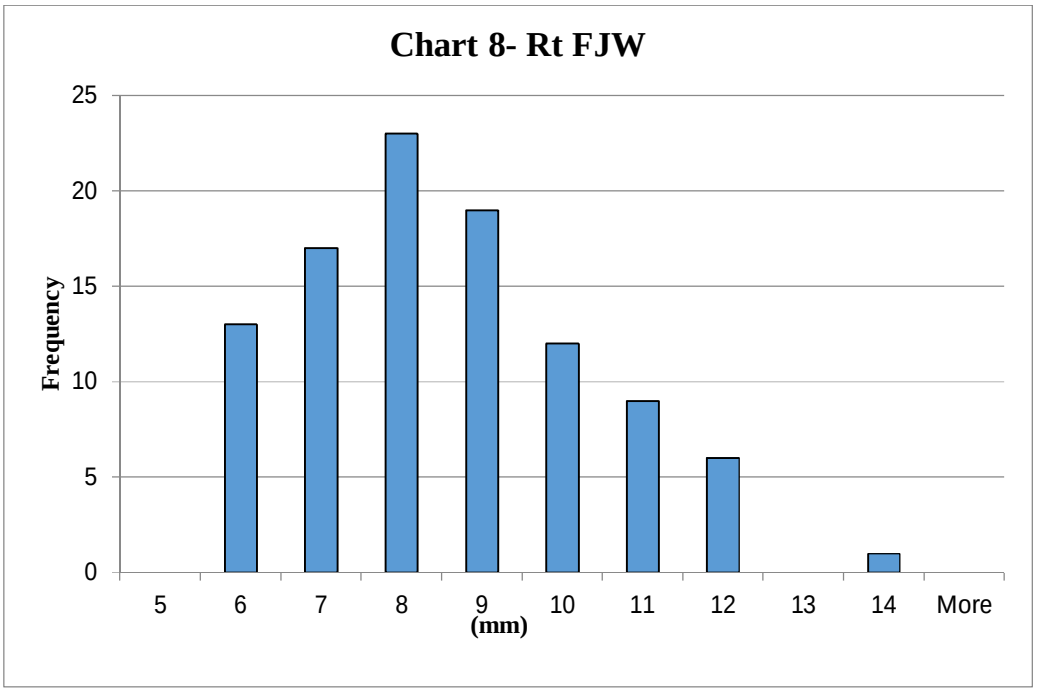


TABLE 9-WIDTH OF LEFT JUGULAR FOSSA (Lt FJW)

STATISTICAL DATA	Lt FJW in mm
No. of skulls	100
Minimum	4.3
Maximum	12.11
Range	7.81
Mean	7.40
Standard Deviation	1.66

The whole range of values is shown in the histogram below

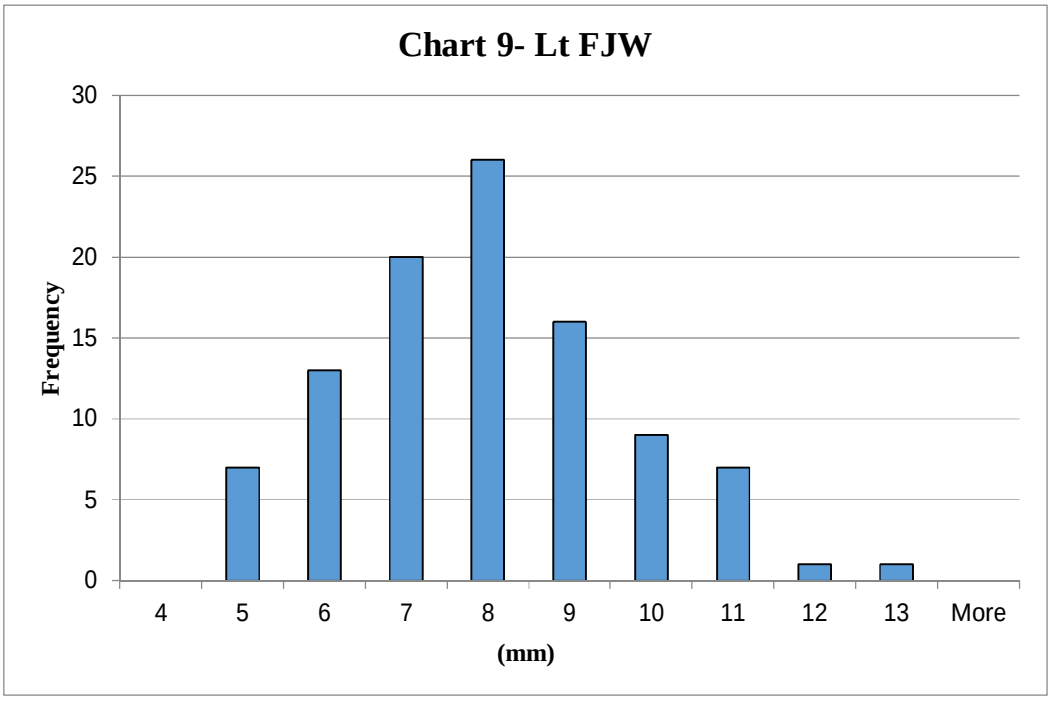


TABLE 10-DEPTH OF RIGHT JUGULAR FOSSA (Rt FJD)

STATISTICAL DATA	RFJD in mm
No. of skulls	100
Minimum	5.06
Maximum	21.79
Range	16.73
Mean	11.20
Standard Deviation	3.07

The whole range of values is shown in the histogram below

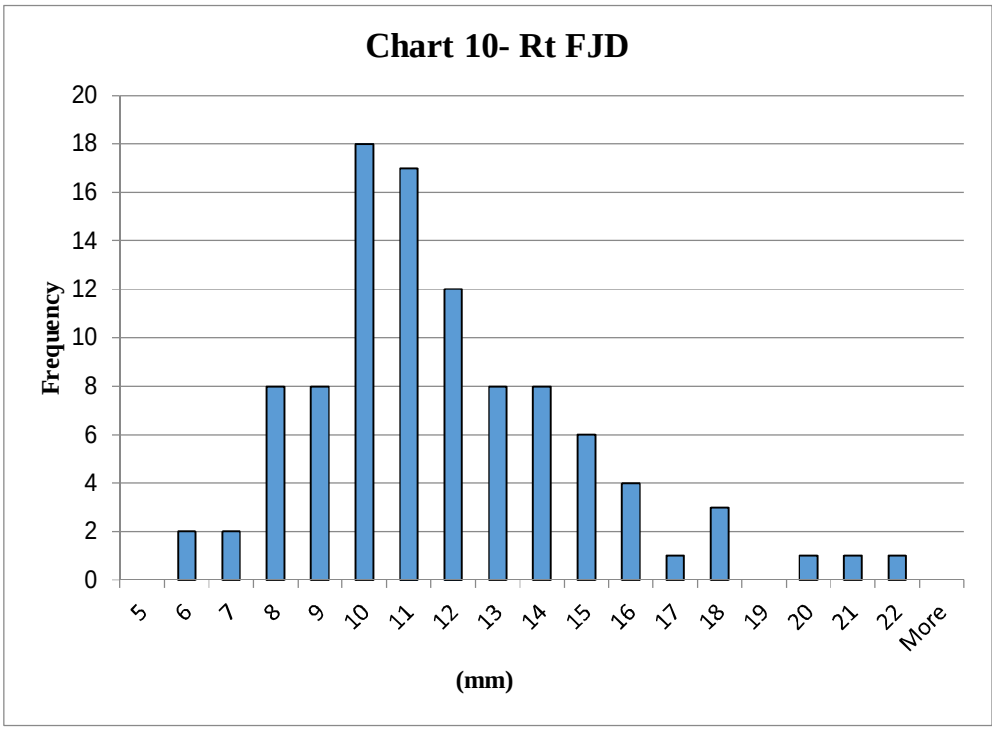


TABLE 11-DEPTH OF LEFT JUGULAR FOSSA (Lt FJD)

STATISTICAL DATA	Lt FJD in mm
No. of skulls	100
Minimum	5.32
Maximum	17.78
Range	12.46
Mean	10.05
Standard Deviation	2.85

The whole range of values is shown in the histogram below

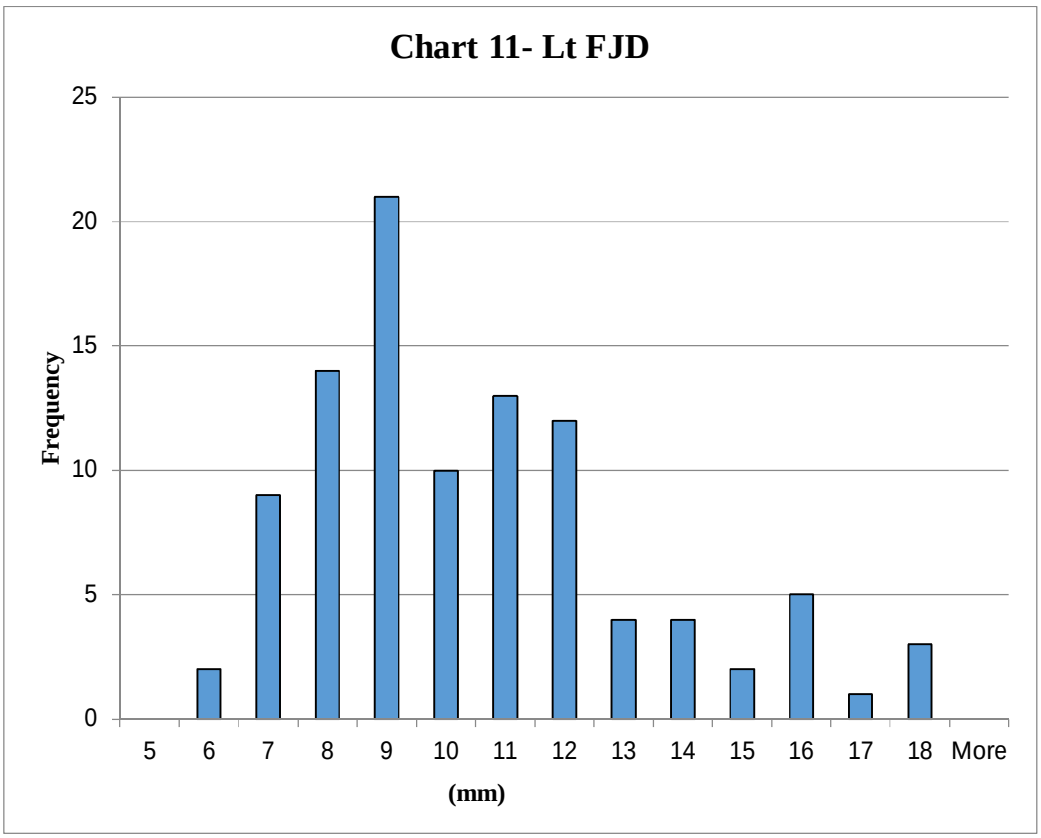


TABLE 12-COMPARISON BETWEEN MEDIOLATERAL DIAMETER (MLD), ANTEROPOSTERIOR DIAMETER (APD) AND AREA OF RIGHT AND LEFT JUGULAR FORAMINA BY PAIRED T TEST.

Parameter (n=100)	Side	Mean	SD	SE	t value	p value
MLD	Right	14.87mm	2.47mm	0.25	3.22	0.0015
	Left	13.76mm	2.37mm	0.24		
APD	Right	11.90mm	1.93mm	0.19	3.85	0.0002
	Left	10.88mm	1.82mm	0.18		
Area	Right	179.23mm^2	49.39mm^2	4.94	4.19	0.04
	Left	151.65mm^2	43.58mm^2	4.36		

The differences in values of the MLD, APD and Area of the Jugular Foramina on right and left sides were found to be statistically significant as the p value was less than 0.05.

TABLE 13-COMPARISON BETWEEN WIDTH OF JUGULAR FOSSA (FJW) AND DEPTH OF JUGULAR FOSSA (FJD) OF BOTH SIDES BY PAIRED T TEST FOR STATISTICAL SIGNIFICANCE

Parameter (n=100)	Side	Mean(mm)	SD(mm)	SE	t value	p value
FJW	Right	7.90	1.80	0.18	2.08	0.04
	Left	7.40	1.66	0.17		
FJD	Right	11.20	3.07	0.30	2.74	0.007
	Left	10.05	2.85	0.28		

The differences in values of the width and depth of the Jugular Fossa on right and left sides were found to be statistically significant as the p value was less than 0.05

TABLE 14-COMPARISON BETWEEN MEDIOLATERAL DIAMETER (MLD) AND ANTEROPOSTERIOR DIAMETER (APD) OF JUGULAR FORAMEN OF THE SAME SIDE FOR CORRELATION.

Sl No.	Parameter (n=100)	Mean (mm)	SD (mm)	Correlation coefficient value
1.	**Rt MLD**	14.87	2.47	0.471
	Rt APD	11.90	1.93	
2.	**Lt MLD**	13.76	2.37	0.407
	Lt APD	10.88	1.82	

TABLE 15-COMPARISON BETWEEN FJW AND FJD OF THE SAME SIDE FOR CORRELATION

Sl No.	Parameter (n=100)	Mean (mm)	SD (mm)	Correlation coefficient value
1.	**Rt FJW**	7.90	1.80	0.196
	Rt FJD	11.20	3.07	
2.	**Lt FJW**	7.40	1.66	0.322
	Lt FJD	10.05	2.85	

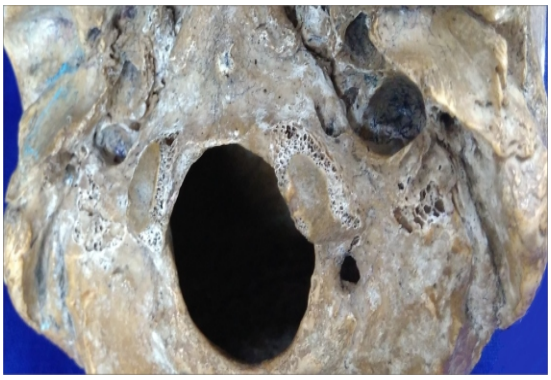
With 100 pairs of observations, critical values of correlation coefficient at various levels of significance are given below.

Level of significance	Critical value
0.05	0.195
0.01	0.254
0.001	0.321

Thus all the four correlations are highly significant and those pairs of characters can be considered to have thick relationship. A positive correlation was observed between mediolateral diameter and anteroposterior diameter of Jugular Foramen on both the sides. A positive correlation was observed between width and depth of Jugular Fossa on both the sides.

(A) Bilateral dome - both equal in depth

(B) Bilateral dome - right deeper



(C) Bilateral dome - left deeper

(D) Unilateral dome on right side

(E) Unilateral dome on left side

(F) Bilateral absence of dome

Fig.21 : Dome of Jugular Fossa.

PRESENCE OF DOMED JUGULAR FOSSA ON RIGHT SIDE AND LEFT SIDE

A dome in the roof of the Jugular Fossa was present bilaterally in 69% of skulls. It was observed unilaterally in 22% on the right side and 5% on the left side. A dome in the roof of the Jugular Fossa was absent bilaterally in 4% of skulls (Fig.21)

TABLE 16-INCIDENCE OF DOMED JUGULAR FOSSA WITH SIDE DISTRIBUTION

Domed Jugular Fossa	Right side (n=100 sides)	Left side (n=100 sides)
Number	91	74
Percentage	91%	74%

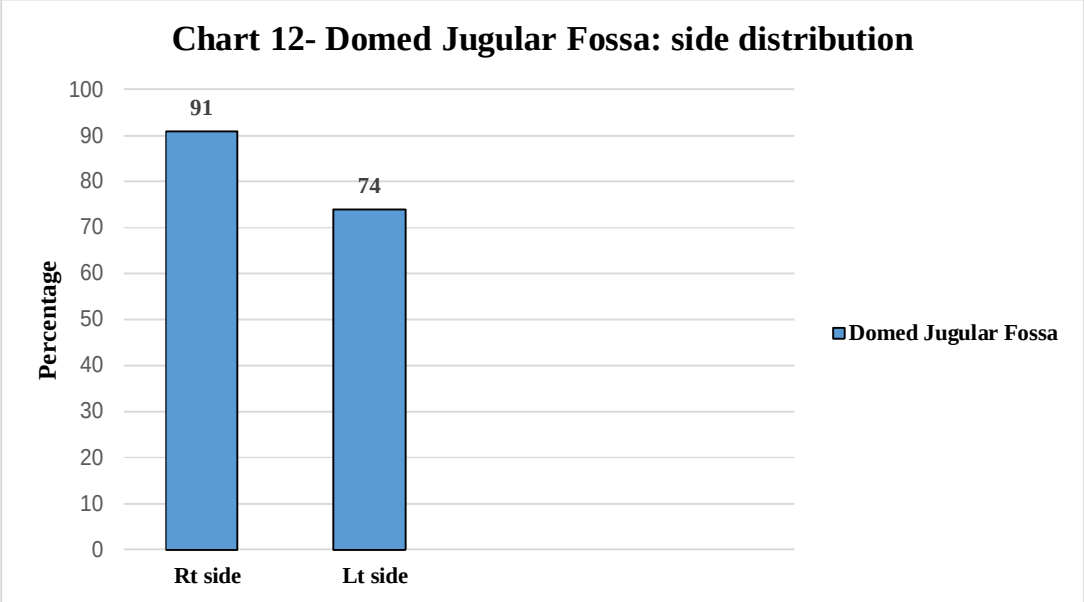


TABLE 17-INCIDENCE OF DOMED JUGULAR FOSSA (n= 100 SKULLS)

Domed Jugular Fossa	Bilaterally present	Unilaterally present		Bilaterally absent
		Right side	Left side	
Number	69	22	5	4
Percentage	69%	22%	5%	4%

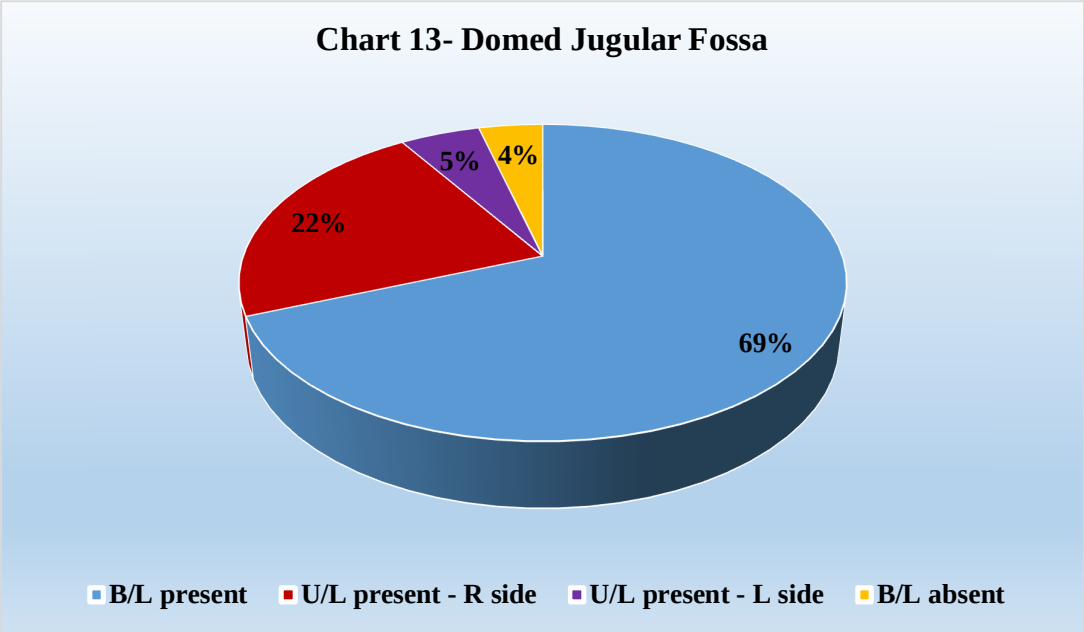
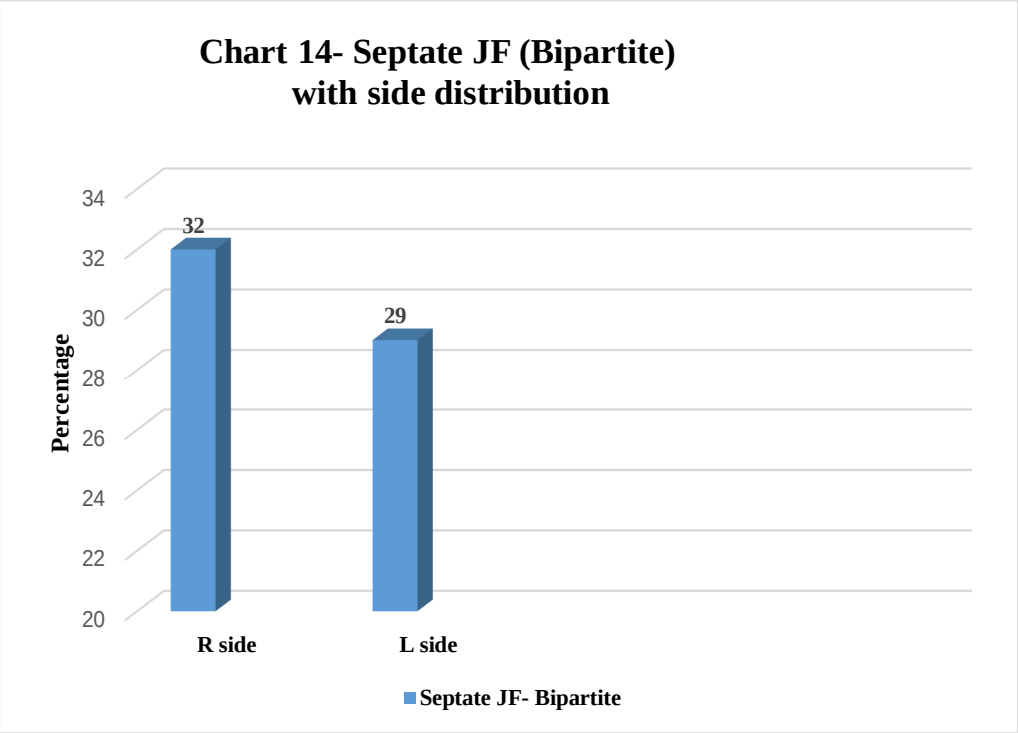
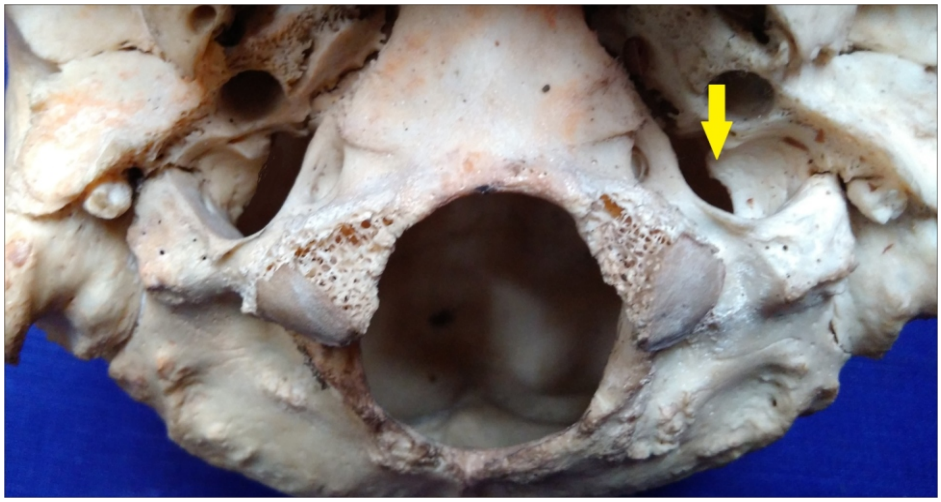


TABLE 18- PRESENCE OF SEPTATE JUGULAR FORAMEN ON RIGHT AND LEFT SIDES.

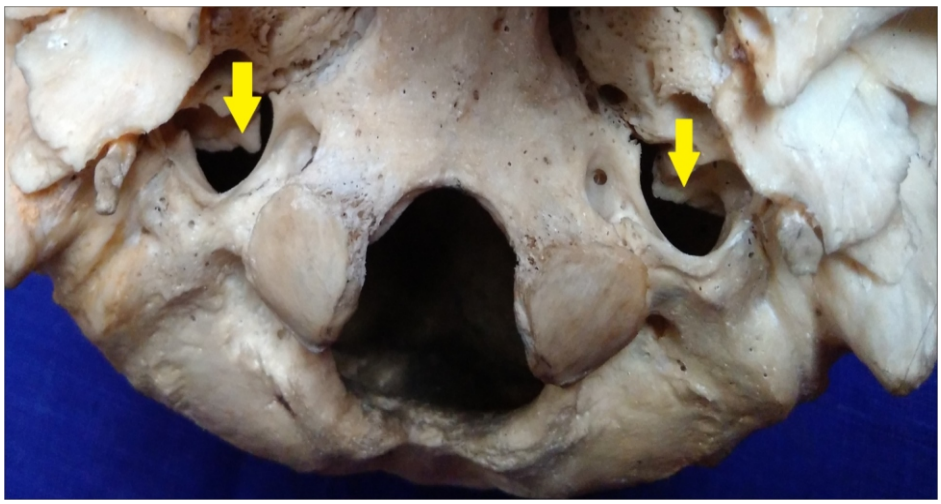
Presence of one septum- Bipartite JF	Right side (n=100 sides)	Left side (n=100 sides)
Number	32	29
Percentage	32%	29%



(A) - Septum absent bilaterally



(B) - Septum present unilaterally



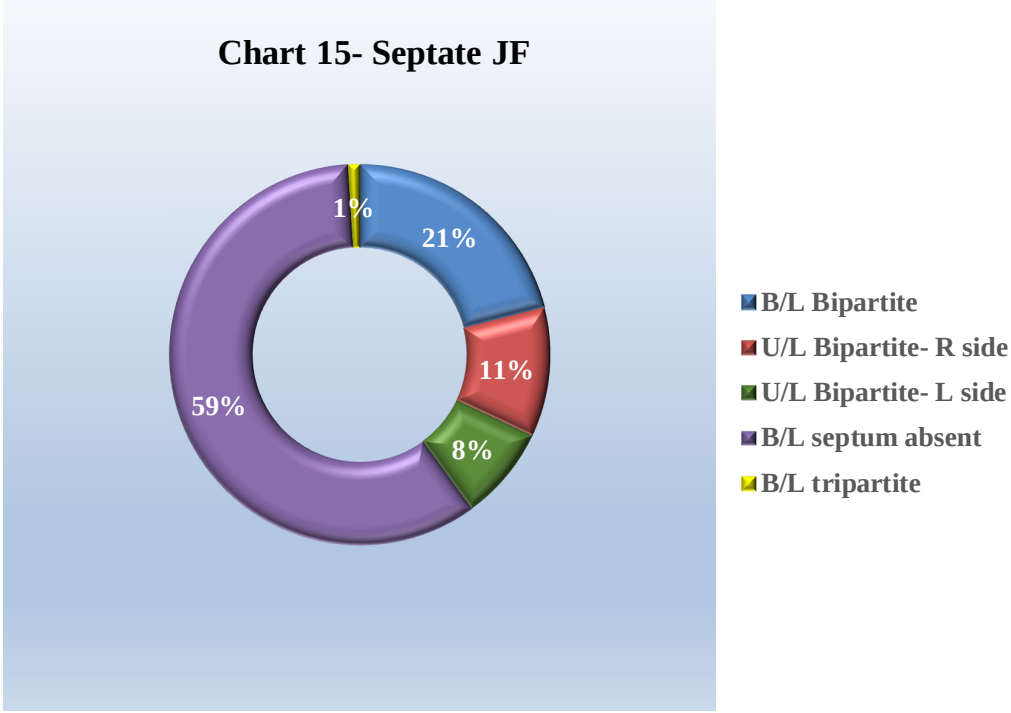
(C) - Septum present bilaterally

Fig.22 : Bipartite Jugular Foramen

TABLE 19- INCIDENCE OF SEPTATE JF, BIPARTITE TYPE (n=100 SKULLS) Fig.22

Bilaterally present (n=100 skulls)	Unilaterally present (n=100 skulls)		Bilaterally absent (n=100 skulls)
	Right side	Left side	
21	11	8	59%
21%	11%	8%	59%

The presence of two septa (tripartite Jugular Foramen) was observed bilaterally in one skull (1%). Fig.23



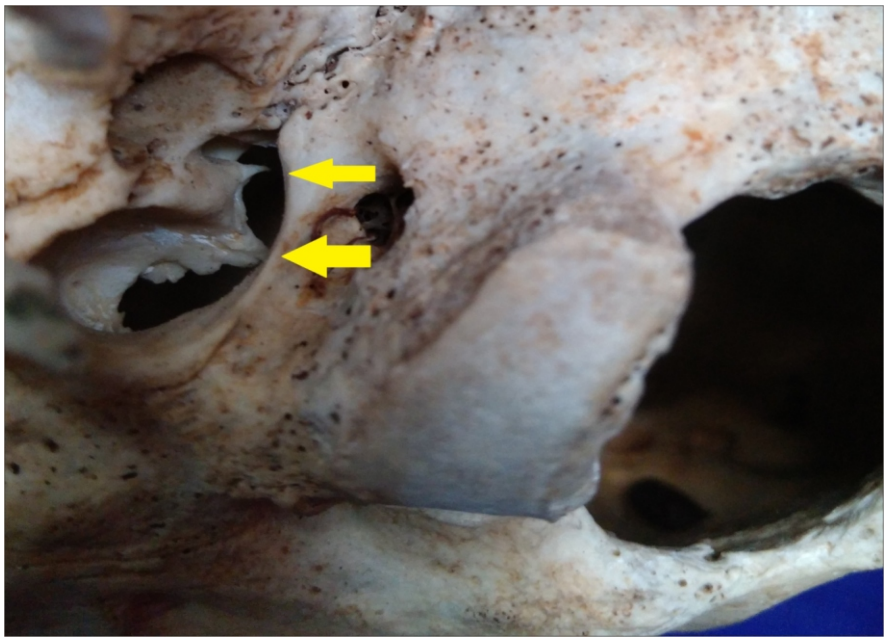
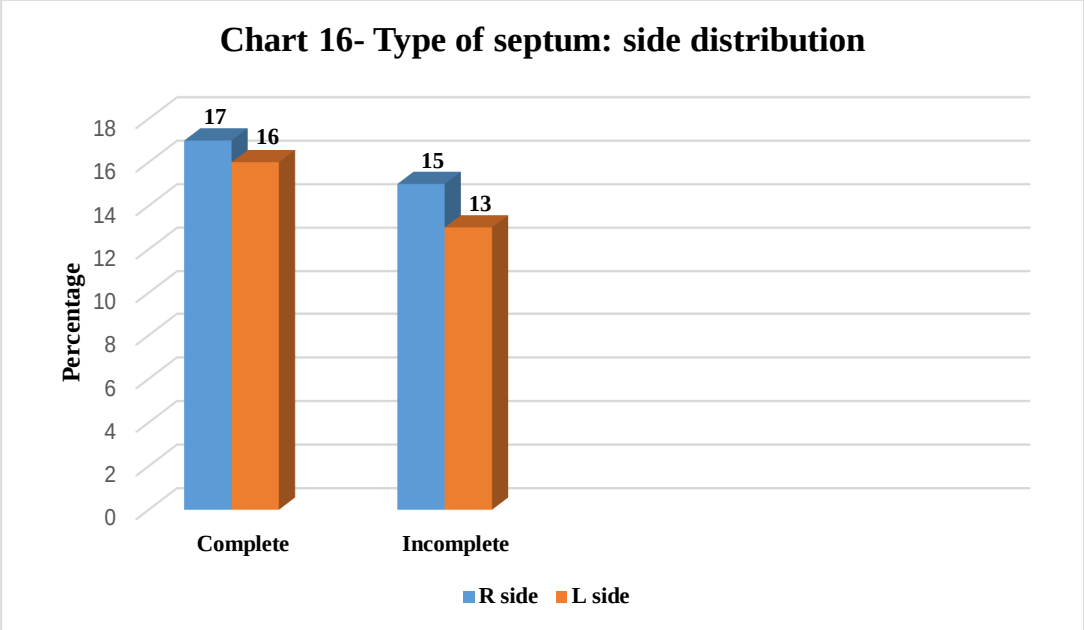
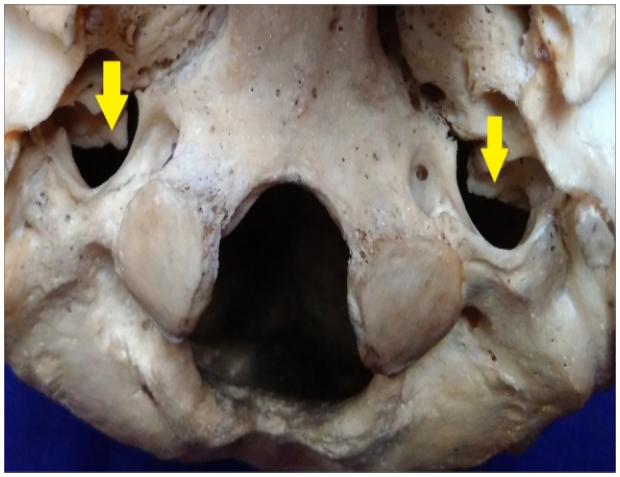


Fig. 23 : Tripartite Jugular Foramen

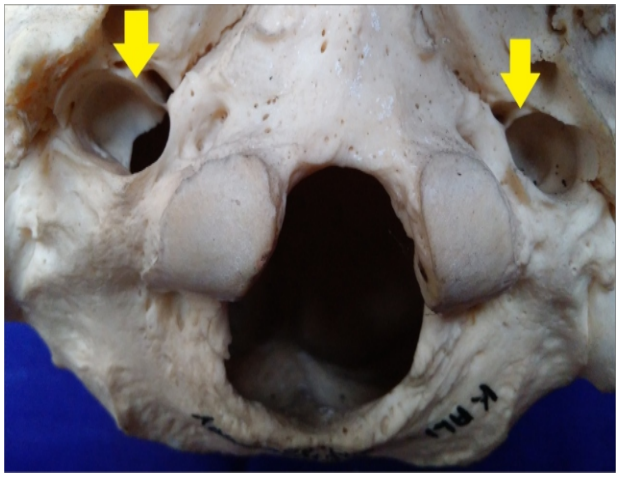
TABLE 20-TYPE OF SEPTUM IN THE JUGULAR FORAMEN WITH SIDE DISTRIBUTION

Type of septum in Bipartite JF		Right side (n=100 sides)	Left side (n=100 sides)
Complete	Number	17	16
	Percentage	17%	16%
Incomplete	Number	15	13
	Percentage	15%	13%



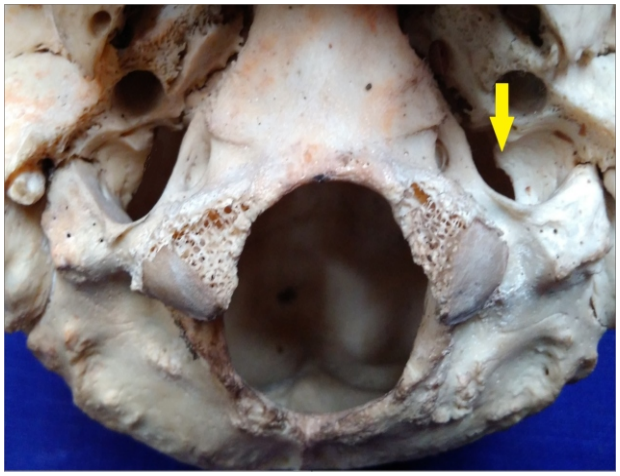


(A) Bilateral incomplete septum



(B) Bilateral complete septum

(C) Bilateral septum



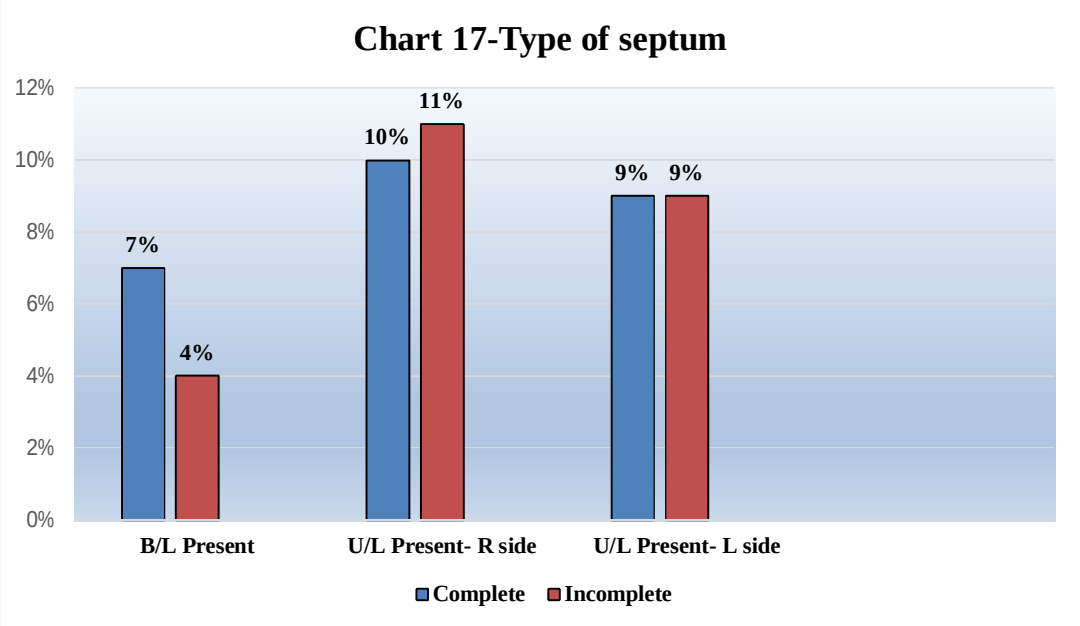
(D) Unilateral incomplete septum

↓ incomplete septum ↓ complete septum

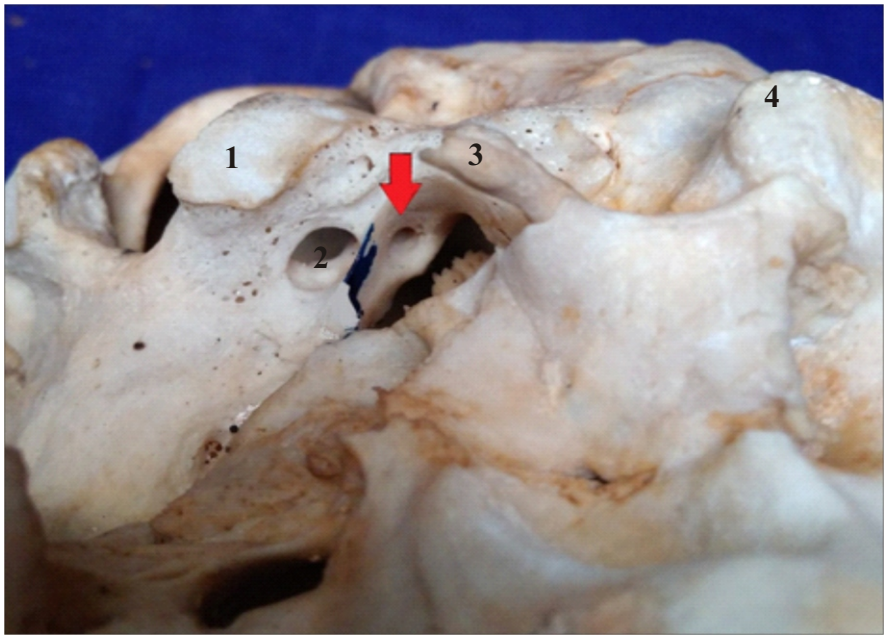
Fig. 24 : Types of septum

TABLE 21- TYPE OF SEPTUM IN THE JUGULAR FORAMEN (n=100 SKULLS) Fig.24.

Type of septum		Bilaterally present	Unilaterally present	
			Right side	Left side
Complete	Number	7	10	9
	Percentage	7%	10%	9%
Incomplete	Number	4	11	9
	Percentage	4%	11%	9%



Tripartite Jugular Foramina, present bilaterally in one skull were each partitioned by one complete septum and one incomplete septum (Fig.23)



1- occipital condyle 2 - anterior condylar canal opening
3 - styloid process 4 - mastoid process

Fig. 25 : Accessory opening in the medial part of posterior wall of Jugular Foramen

TABLE 22- PRESENCE OF ACCESSORY OPENING IN THE WALLS OF JUGULAR FORAMEN ON RIGHT AND LEFT SIDES

Accessory opening was found in 7% on the right side and 4% on the left side. All the accessory openings were on the medial part of the posterior wall of JF. (Fig.25)

Presence of accessory opening	Right side (n=100 sides)	Left side (n=100 sides)
Number	7	4
Percentage	7%	4%

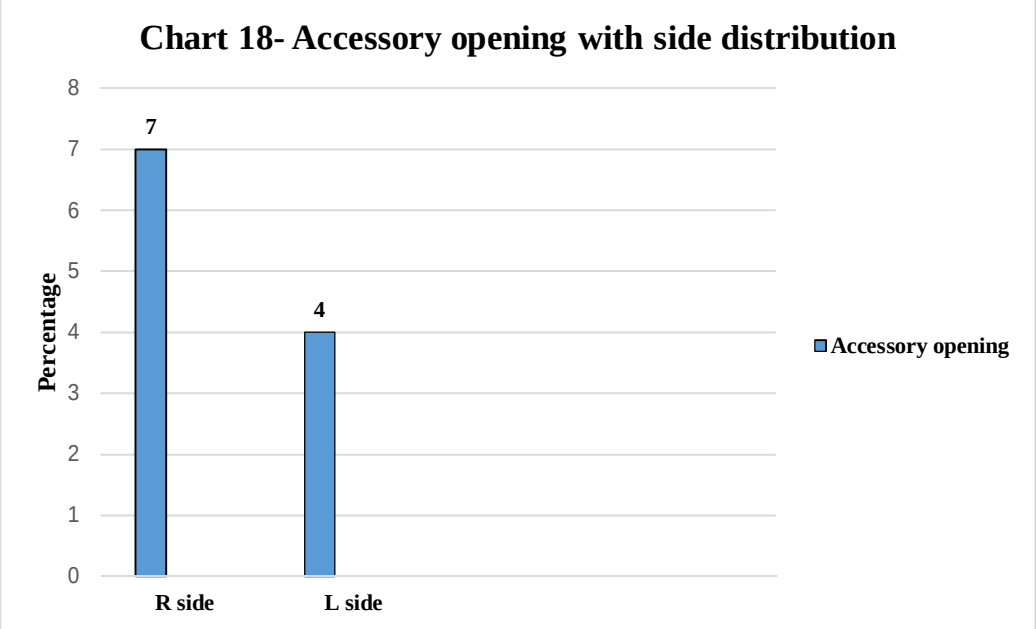
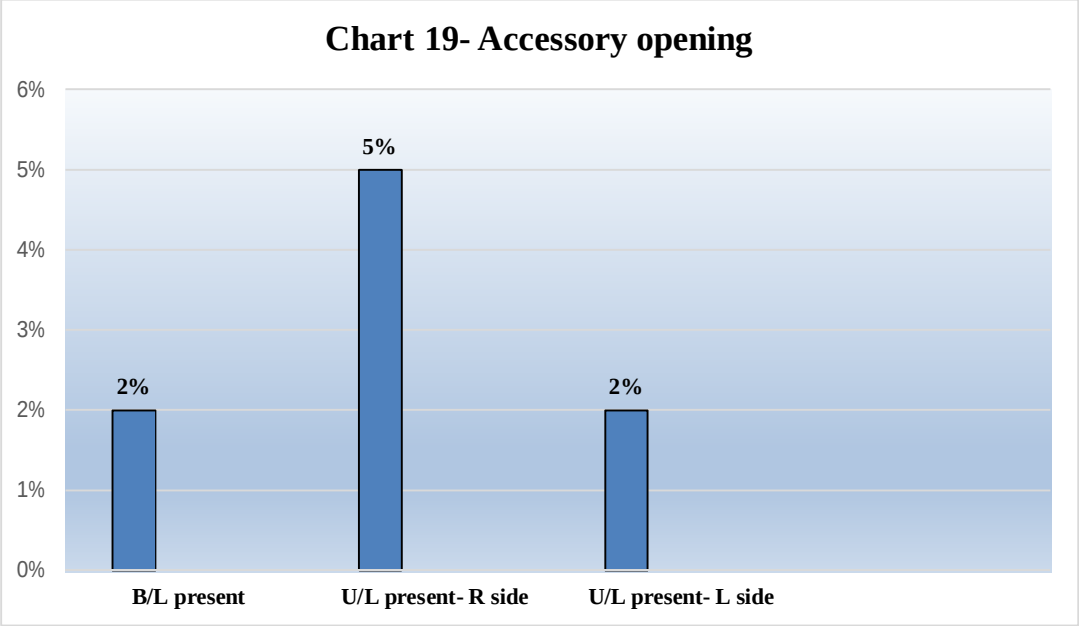
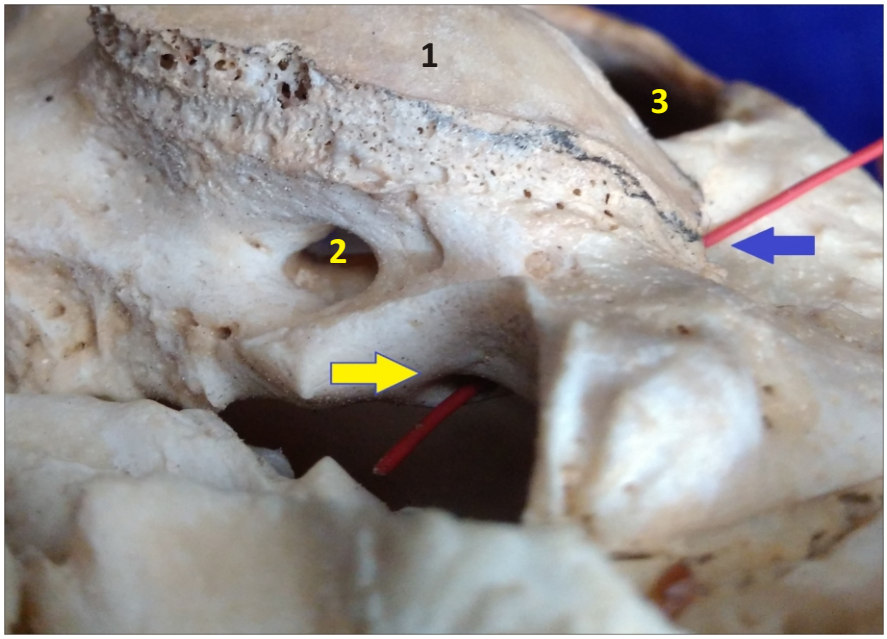


TABLE 23- INCIDENCE OF ACCESSORY OPENING IN THE WALLS OF JUGULAR FORAMEN (n=100 SKULLS)

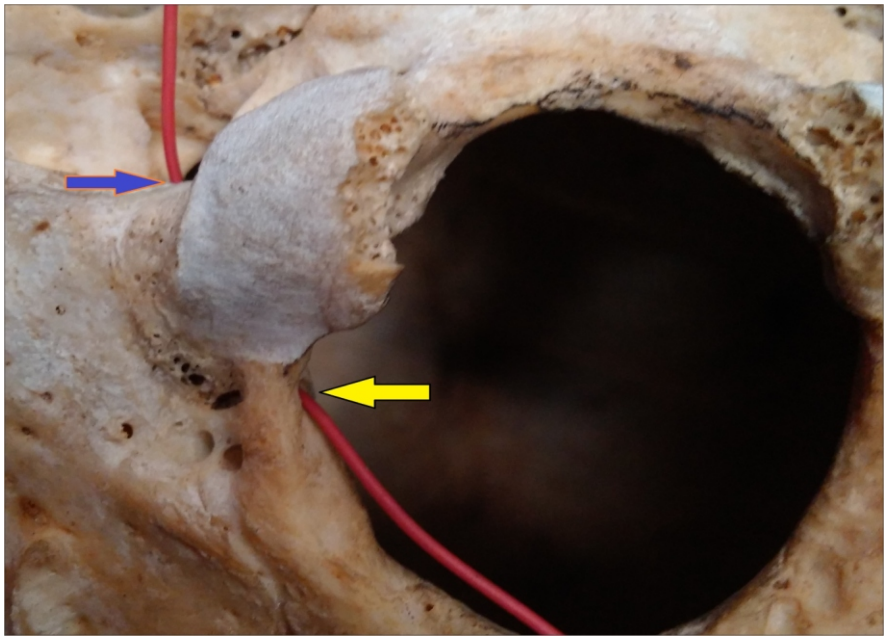
Presence of accessory opening	Bilaterally present	Unilaterally Present	
		Right side	Left side
Number	2	5	2
Percentage	2%	5%	2%





(A) Leading to posterior condylar canal

1 - Occipital condyle 2 - Anterior condylar canal 3 - Foramen Magnum



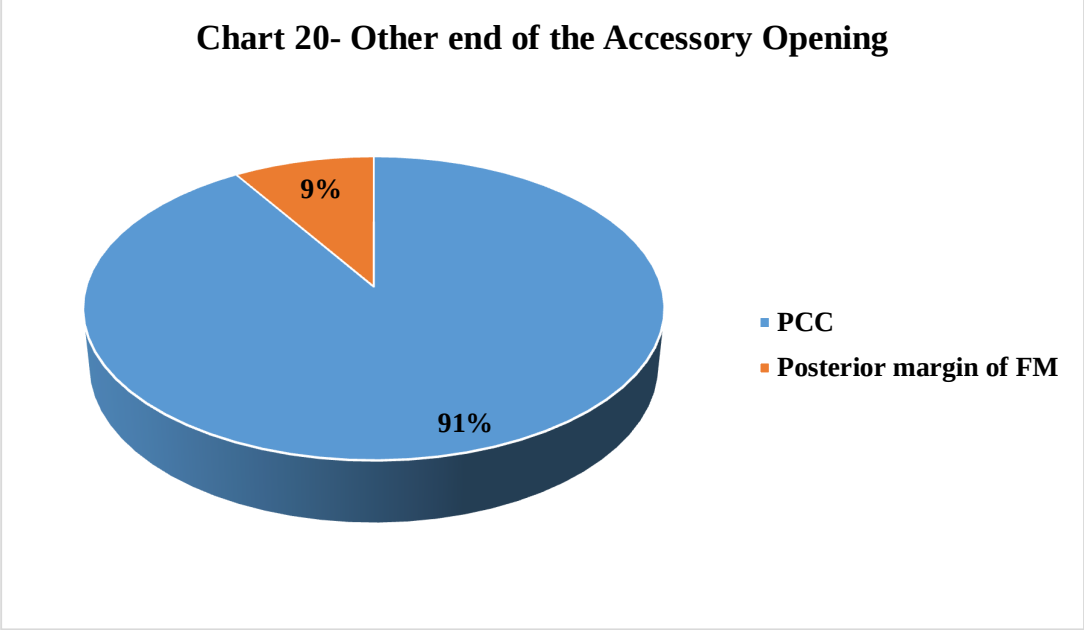
(B) Leading to posterior margin of Foramen Magnum

Fig. 26 : Probe in the accessory opening

TABLE 24- SITE WHERE THE ACCESSORY OPENING LEADS TO

Site where the accessory opening leads to.	Posterior condylar canal	Posterior margin of Foramen Magnum
Number	10	1
Percentage	91%	9%

Out of the 11 accessory openings, ten (91%) led to the posterior condylar canal (PCC)-Fig.26A.One accessory opening (9%) on the right side led to a canal which opened at the posterior margin of foramen magnum(FM)- Fig.26B.



Discussion

DISCUSSION

Findings of the present study were compared with those of similar studies conducted in India and abroad.

MEDIOLATERAL DIAMETER (MLD) OF THE JUGULAR FORAMEN

OE Idowu[34] (2004) studied 40 JF of 20 Nigerian skulls and stated that the mean MLD on the right (Rt MLD) and left (Lt MLD) were 13.90 mm and 14.11 mm respectively.

Ekinci et al[15] (2009) conducted a study on 70 skulls of Turkish population and reported that Rt MLD was 16.0mm and Lt MLD was 15.5 mm.

Namita A Sharma et al[33] (2011) studied the Jugular Foramina in 50 dry skulls and found that Rt MLD and Lt MLD were 15.59+/- 2.64mm and 13.83+/- 4.94mm respectively.

Ketu Chauhan et al[28] (2011) analysed 50 dry skulls and reported that Rt MLD and Lt MLD were 13.46mm and 13.10mm respectively.

Anitha MR et al[3] (2013) in their study of 100 adult dry skulls observed that the mean Rt MLD and Lt MLD were 15.21mm and 13.39mm respectively.

Shifan Khanday et al[48] (2013) studied 648 JF of 324 skulls and found that mean Rt MLD was 14.6 mm and mean Lt MLD was 13.9 mm.

N. Himabindu et al[32] (2015) studied the JF of 110 adult dry skulls and reported that mean Rt MLD was 14.6mm and mean Lt MLD was 12.69mm.

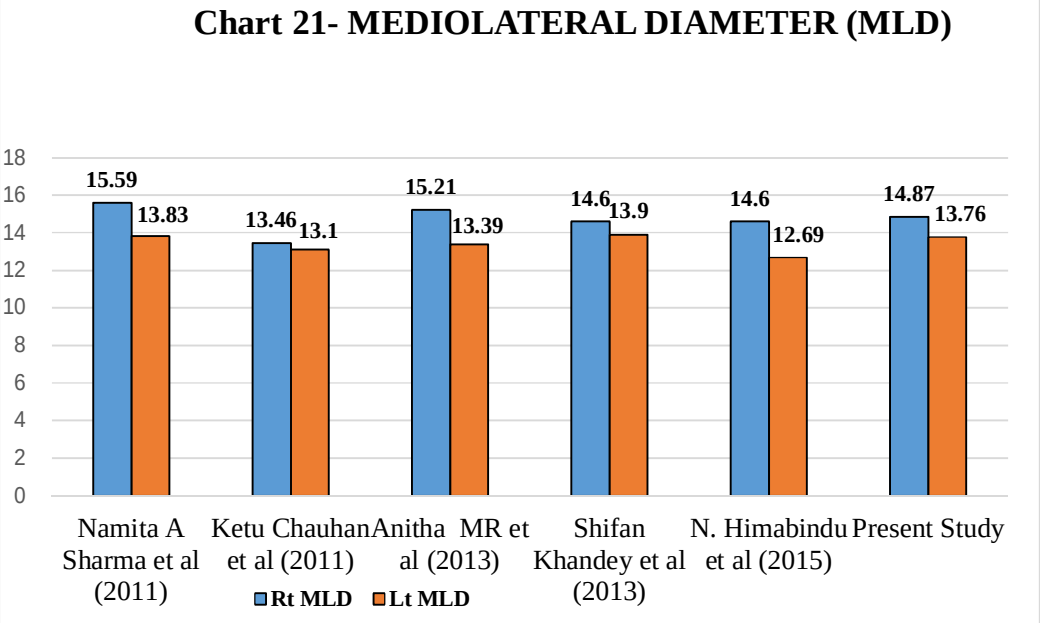
In the present study, the mediolateral diameter of right JF ranged from 9.24mm to 20.06mm with mean as 14.87+/- 2.47mm. The mediolateral diameter of left JF ranged from 8.34mm to 19.68mm with mean as 13.76+/- 2.37mm. The mean RMLD and LMLD of the present study coincided with the values of all these studies (Table 25) except OE Idowu et al (RMLD 13.9mm and LMLD 14.11mm, with the value on right side being smaller than the value on left side) and Ekinci et al (RMLD 16.0mm and LMLD 15.5mm). This could be due to racial differences in the skulls.

Accurate knowledge about these dimensions is essential for neurosurgeons operating on the JF region. In the present study, the mean MLD is greater on the right side. This goes well with the fact that right

IJV is larger than the left in most of the individuals. The larger superior sagittal sinus continues in succession as right transverse sinus, right sigmoid sinus and right IJV, on the other hand the smaller inferior sagittal sinus continues in succession as straight sinus, left transverse sinus, left sigmoid sinus and left IJV.[7,61]

TABLE 25 SHOWING STUDIES WITH COMPARABLE VALUES OF MEDIOLATERAL DIAMETER (MLD) OF THE JF.

Sl No.	Authors	Rt MLD(mm)	Lt MLD(mm)
1.	Namita A Sharma et al (2011)	15.59	13.83
2.	Ketu Chauhan et al (2011)	13.46	13.10
3.	Anitha MR et al (2013)	15.21	13.39
4.	Shifan Khandey et al (2013)	14.6	13.9
5.	N. Himabindu et al (2015)	14.6	12.69
6.	**Present Study**	**14.87**	**13.76**



ANTEROPOSTERIOR DIAMETER (APD) OF THE JUGULAR FORAMEN

Ekinci et al[15] (2009) conducted a study on 70 skulls of Turkish population and reported that APD on the right side (Rt APD) was 8.4mm and on the left side(Lt APD) was 7.6 mm.

Osunwoke EA et al[35] (2012) in their study of 120 dry skulls reported that Rt APD and Lt APD were 9.34±0.18mm and 7.54±0.20mm respectively.

Anitha MR et al[3] (2013) in their study of the JF of 100 adult dry skulls observed that the mean Rt APD and Lt APD were 10.13mm and 8.81mm.

Shifan Khanday et al[48] (2013) studied 648 JF of 324 skulls and found out that the mean Rt APD and mean Lt APD were 10.06mm and 8.9mm.

Vijisha P et al[57] (2013) studied 30 adult dry skulls and reported that the mean Rt APD was 12.13mm and the mean Lt APD was 9.27mm.

Avanish Kumar et al[5] (2014) in their study of JF of 68 skulls, stated that the mean Rt APD was 10.6mm and Lt APD was 9.2 mm.

Chandni Gupta et al[9] (2014) studied 50 adult dry skulls and reported that mean Rt APD and Lt APD were 11.22 mm and 9.52 mm.

N. Himabindu et al[32] (2015) analysed the JF of 110 adult dry skulls and reported that mean Rt APD was 9.61mm and mean Lt APD was 8.24mm.

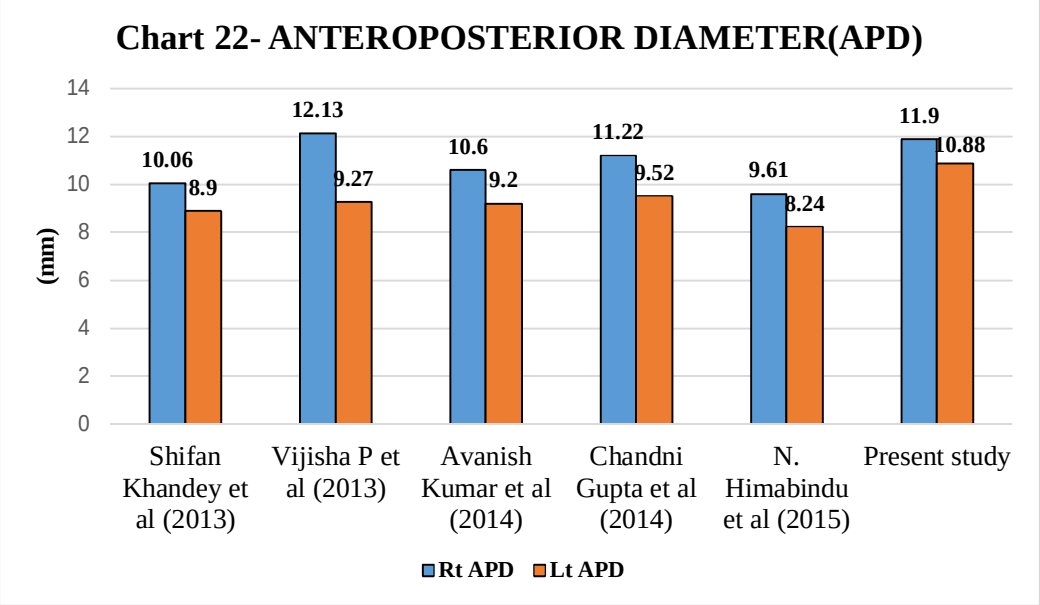
In the present study the Rt APD ranged from 7.59mm to 15.89mm with mean as 11.90 +/-1.93mm. The Lt APD ranged from 7.29mm to 15.23mm with mean as 10.88+/-1.82 mm. The mean Rt APD and Lt APD of the present study were in concurrence with all these studies (Table 26) except Ekinci et al (mean Rt APD 8.4mm and mean Lt APD 7.6 mm) and Osunwoke et al (mean Rt APD 9.34±0.18mm and mean Lt APD 7.54± 0.20mm), probably due to racial differences in the skulls.

These dimensions are of relevance to neurosurgeons and vascular surgeons operating on JF tumours like the glomus jugulare and the anteriorly related carotid canal. Mean Rt APD is greater than the mean Lt APD and this can be attributed to the size difference between right and left IJV where the right is larger than the left in most of the individuals. The difference in size of the two internal jugular veins, when present, is visible in the 23mm stage human embryo (8weeks post conception) and

probably results from differences in the pattern of development of right and left brachiocephalic veins.[36]

TABLE 26 SHOWING STUDIES WITH COMPARABLE VALUES OF ANTEROPOSTERIOR DIAMETER (APD) OF THE JF.

Sl. No.	Authors	Rt APD(mm)	Lt APD(mm)
1.	Shifan Khandey et al (2013)	10.06	8.9
2.	Vijisha P et al (2013)	12.13	9.27
3.	Avanish Kumar et al (2014)	10.6	9.2
4.	Chandni Gupta et al (2014)	11.22	9.52
5.	N. Himabindu et al (2015)	9.61	8.24
6.	**Present study**	**11.90**	**10.88**



AREA OF JUGULAR FORAMEN

OE Idowu[34] (2004) studied 40 JF of 20 Nigerian skulls and stated that mean JF area on the right (Rt AJF) was 437.49 mm2 and that on the left (Lt AJF) was 419.48 mm2.

Shifan Khanday et al[48] (2013) in their study of 648 Jugular Foramina of 324 skulls, found that the mean Rt AJF was 118 mm^2 and Lt AJF was 90 mm^2.

Vijisha P et al[57] (2013) in their study of 30 adult dry skulls reported that the mean Rt AJF was 210.87mm^2 and mean Lt AJF was 141.93 mm^2.

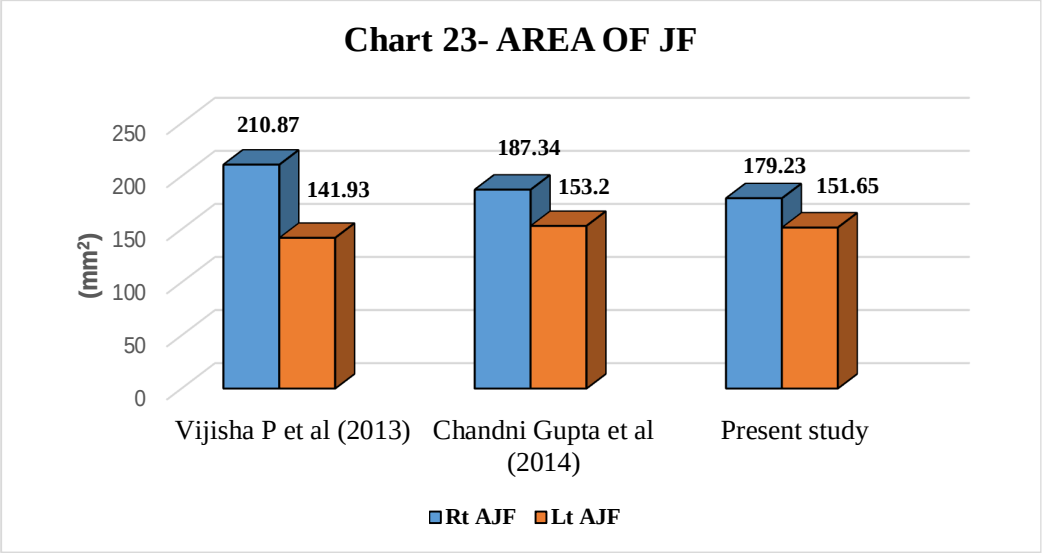
Chandni Gupta et al[9] (2014) studied 50 adult dry skulls and observed that mean Rt AJF and mean Lt AJF were 187.34 mm^2 and 153.2 mm^2 respectively.

In the present study the area of the Jugular Foramen on the right side ranged from 70.13 mm^2 to 305.41 mm^2 with mean as 179.23+/-49.39mm^2. On the left side it ranged from 78.38 mm^2 to 294.81 mm^2 with mean as 151.65+/-43.58 mm^2. The mean Rt AJF and Lt AJF of the present study were coinciding with those of all these studies (Table27) except OE Idowu et al (mean Rt AJF 437.49 mm^2 and mean Lt AJF 419.48 mm^2), probably due to racial differences in the skulls.

The wide range of values raise concern as this can modify the topical relations of JF and the structures within it, thereby producing otologic implications. This warrants caution to the neurosurgeons and ear surgeons to prevent intra operative as well as postoperative complications. The mean area on the right side is more than that on the left side, suggesting that right JF plays greater role than the left in venous drainage of the cranial cavity and its contents.[47]This can be attributed to the IJV being larger on the right side in most of the individuals.

TABLE 27 SHOWING STUDIES WITH COMPARABLE VALUES OF AREA OF THE JF.

Sl No.	Authors	Rt AJF(mm^2)	Lt AJF(mm^2)
1.	Vijisha P et al (2013)	210.87	141.93
2.	Chandni Gupta et al (2014)	187.34	153.2
3.	**Present study**	**179.23**	**151.65**



SIDE DOMINANCE OF JUGULAR FORAMEN

Wysocki et al[24] (2006) in their study of 100 adult human dry skulls observed that in 54% of the skulls there was right sided dominance of JF compared to 27% of the skulls with a left sided dominance. In the remaining 19% of skulls there was symmetry with no dominance.

Ekinci et al[15] (2009) conducted a study on 70 skulls of Turkish population and reported that right JF was larger than left in 61.4%, left was larger in 24.3% and both were equal in 14.3%.

Hussain Saheb et al[20] (2010) in their study of 125 adult dry skulls observed that right JF was larger than left in 64.8% and equal in size to the left in 10.4%, the remaining skulls had a larger JF on the left.

Rahul Rai et al[41] (2013) in their study of 100 dry skulls observed that right JF was larger than left in 74%, smaller in 19% and both were equal in size in 7%.

Roma Patel et al[44] (2014) studied 100 dry skulls and observed that the size of the JF varied with side. Right JF larger than the left were 75%, right smaller than the left were 23% and both were of equal size in 2%.

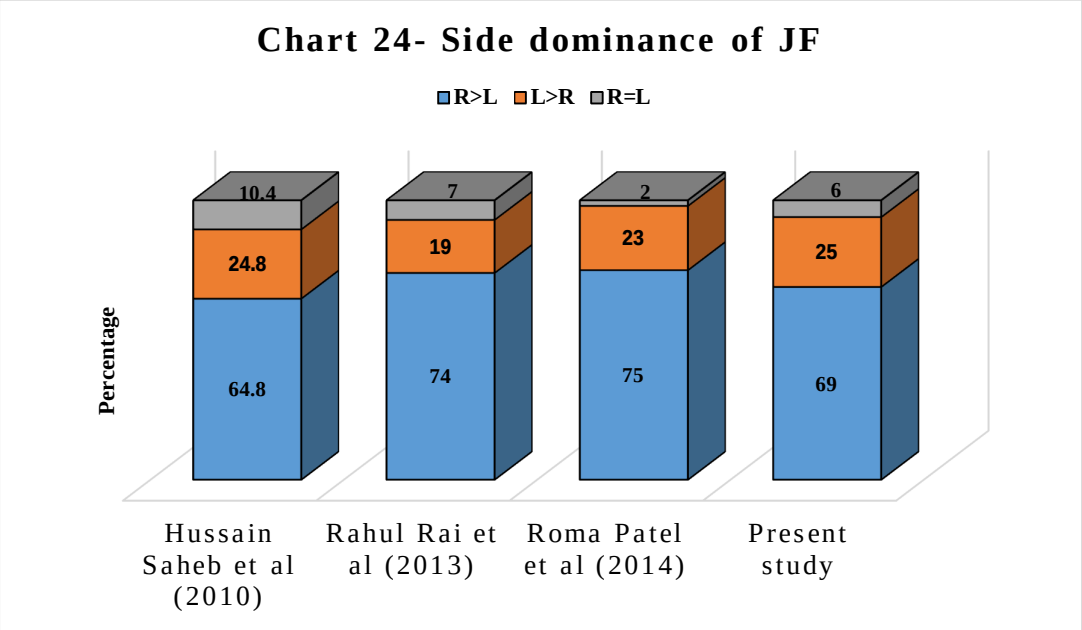
In the present study the area of the right Jugular Foramen was larger than the left in 69%, the left was larger in 25% and both were equal

in 6% of skulls. The side predominance observed in the present study was similar to all these studies (Table 28) except Ekinci et al who reported symmetry more frequently (right- 61.4%, left-24.3%, no dominance in 14.3%). This could probably be due to racial variations in the skulls.

Right sided JF dominance of 69% observed in the present study goes well with right sided jugular venous dominance occurring in 70% to 80% of cases.[11] During surgeries like radical neck dissection, destruction of IJV, especially at the dominant side, may lead to cerebral haemorrhage, infarct and dural arteriovenous malformations.[12,24] The knowledge is also useful to interventionists performing cannulation of IJV.

TABLE 28 SHOWING STUDIES WITH COMPARABLE RESULTS OF SIDE DOMINANCE OF JUGULAR FORAMEN.

Sl No.	Authors	R>L (%)	L>R (%)	R=L (%)
1.	Hussain Saheb et al (2010)	64.8	24.8	10.4
2.	Rahul Rai et al (2013)	74	19	7
3.	Roma Patel et al (2014)	75	23	2
4.	**Present study**	**69**	**25**	**6**



WIDTH OF JUGULAR FOSSA (FJW) AND DEPTH OF JUGULAR FOSSA (FJD)

Aydinlioglu A et al[6] (2001) studied Eastern Anatolian skulls and reported that the FJD were 14mm and 13.7 mm on the right and left sides respectively.

Anjali Singla et al[4] (2012) in their study of 50 adult dry skulls observed that the mean FJW were 8.99mm on the right side (Rt FJW) and 7.54mm on the left side (Lt FJW). They also reported that the mean right FJD (Rt FJD) was 11.11mm and mean left FJD (Lt FJD) was 11.04mm.

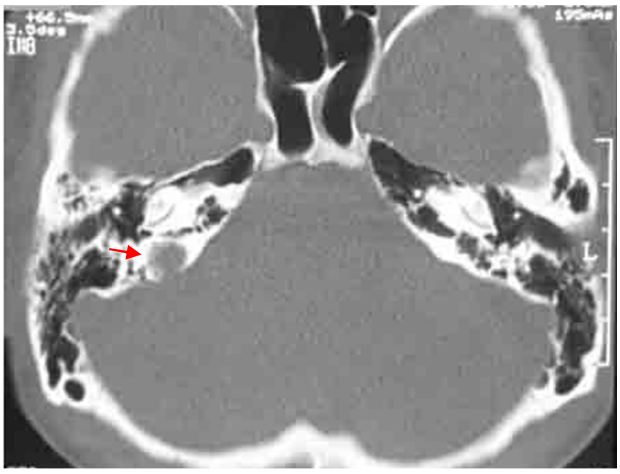
Chandni Gupta et al[9] (2014) studied 50 adult dry skulls and reported that the mean Rt FJW and Lt FJW were 6.83 mm and 5.69mm

respectively. The mean Rt FJD and Lt FJD were 11.58mm and 11.13mm respectively.

In the present study, the width of the Jugular Fossa on the right side was in the range of 5.02mm to 13.34mm with the mean as 7.90+/- 1.80mm. The width of the left Jugular Fossa was in the range of 4.3mm to 12.11mm and the mean was 7.40+/-1.66mm.The depth of the right Jugular Fossa was in the range of 5.06 mm to 21.79mm and the mean was 11.20+/- 3.07mm. The depth of the left Jugular Fossa was in the range of 5.32mm to 17.78mm and the mean was 10.05 +/- 2.85mm. The values of the present study were in concurrence with those of all these studies (Table 29) except Aydinlioglu A et al (mean Rt FJD 14mm and mean Lt FJD 13.7 mm), probably due to racial variations in the skulls.

The size of Jugular Fossa is related to the presence or absence of a prominent superior bulb of IJV.[19,40] The jugular bulb has great anatomic variations in dimensions.[13] Occasionally there may be an excessive enlargement of the jugular bulb(JB) or ectasia of the jugular bulb, causing a larger Jugular fossa resulting in upward arching of the internal auditory canal and inner ear, which might cause tinnitus, dizziness, or mild hearing impairment.[56] It could also cause complications like profuse bleeding and air embolism during surgical interventions.[22,43]

An asymmetrically large JB and Jugular Fossa is a common finding which becomes an imaging problem, when the radiologist discovers it during evaluation of tinnitus, rarely it being the cause. The JB is asymmetrically large, twice that on the other side. Paragangliomas can be ruled out by the preservation of normal bony margins and intact intrajugular process (septum) in the asymmetrically but proportionately enlarged Jugular Foramen as the Jugular Fossa.[16]

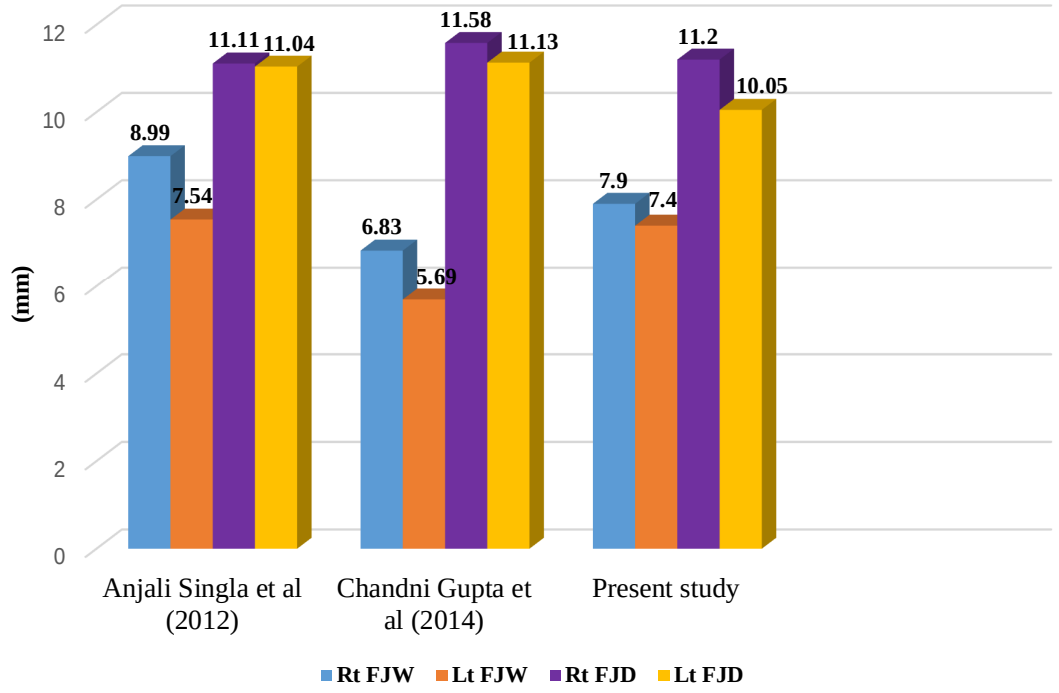


Coronal Computerised Tomography image showing deeper Jugular Fossa with a prominent jugular bulb on the right side.

TABLE 29 SHOWING STUDIES WITH COMPARABLE RESULTS OF WIDTH (FJW) AND DEPTH (FJD) OF THE JUGULAR FOSSA.

Parameter	Anjali Singla et al (2012)	Chandni Gupta et al (2014)	**Present study**
Rt FJW(mm)	8.99	6.83	**7.90**
Lt FJW(mm)	7.54	5.69	**7.40**
Rt FJD(mm)	11.11	11.58	**11.20**
Lt FJD(mm)	11.04	11.13	**10.05**

Chart 25- Width (FJW) and Depth (FJD) of Jugular Fossa



PRESENCE OF DOMED JUGULAR FOSSA

H.L. Guido et al[19](1997) studied 100 Brazilian skulls and stated that dome was present bilaterally in 86%, unilaterally on right side in 10% and left side in 4%.

Hussain Saheb et al[20] (2010) studied 125 adult dry skulls and observed that dome was present bilaterally in 49.6%, unilaterally on right side in 27.2% and left side in 8.8% and was absent in 14.4%.

Namita A Sharma et al[33] (2011) in their study of 50 dry skulls said that the dome was present bilaterally in 58%, unilaterally on right side in 28% and on left side in 8%.

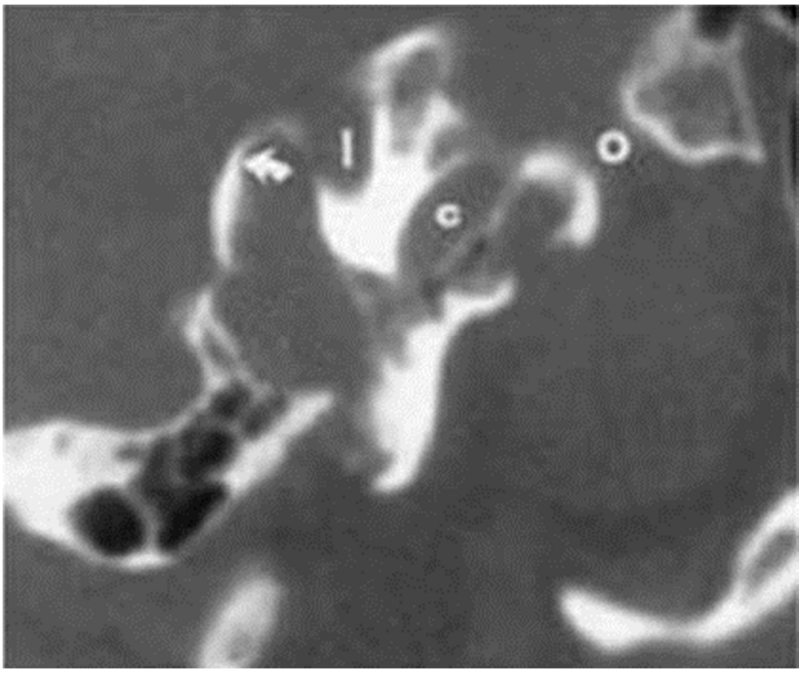
Vijisha P et al[57] (2013) in their study of 30 adult dry skulls reported that dome was observed on right side in 26.6% and left side in 3.33 % and bilaterally in 70%.

Avanish Kumar et al[5] (2014) in their study of JF of 68 skulls, stated that the dome was observed bilaterally in 57.35%, only on right side in 29.4%, only on left side in 8.82% and was absent bilaterally in 4.41%.

In the present study, a dome in the roof of the Jugular Fossa was present bilaterally in 69%, unilaterally in 22% on the right side and 5%

on the left side and absent bilaterally in 4% of skulls. The observations of the present study were similar to all these studies (Table 30) except H.L.Guido et al (bilateral presence in 86%, unilateral on the right side in 10% and left side in 4%), this could be due to racial variations in the skulls.

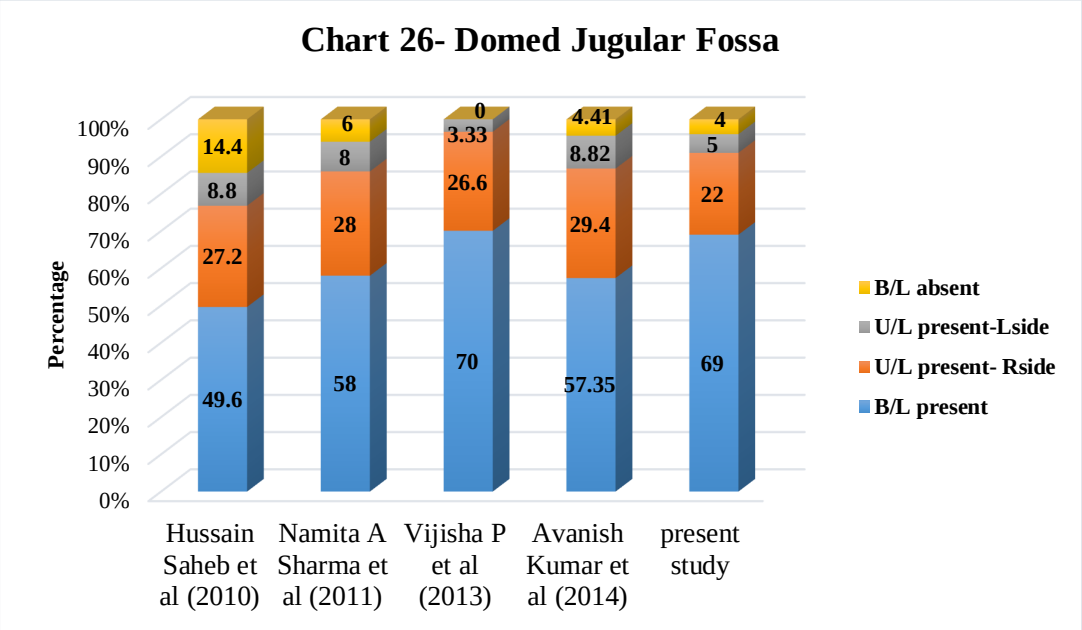
More frequent drainage of superior sagittal sinus through right transverse, then right sigmoid sinus and right IJV might be associated with the greater incidence of prominent superior jugular bulb(JB) and dome of jugular fossa on the right side.[21] An exposed jugular bulb characterised by absence of dome is more prone to injury in middle ear surgeries, especially because the vessel wall is thin in this area.[13] The upper extremity of jugular bulb is at the level of Jugular Fossa dome.[43] A high JB, characterised by a deep dome requires modification of surgical technique by lowering the jugular bulb to explore the lower cranial nerves, during translabyrinthine and retrosigmoid approaches for cerebellopontine angle tumours in lateral skull base surgery as work area inferior to the internal acoustic canal is considerably reduced.[31,43] So the data will be useful to ENT surgeons and neurosurgeons.



Sagittal Computerised Tomography image showing deep dome of Jugular Fossa (marked by arrow), I- internal acoustic meatus, C- carotid canal, O- foramen ovale.

TABLE 30 SHOWING STUDIES WITH COMPARABLE INCIDENCE OF DOMED JUGULAR FOSSA

Sl No.	Authors	B/L present (%)	U/L present- Right side (%)	U/L present- Left side (%)	B/L absent (%)
1.	Hussain Saheb et al (2010)	49.6	27.2	8.8	14.4
2.	Namita A Sharma et al (2011)	58	28	8	6
3.	Vijisha P et al (2013)	70	26.6	3.33	0
4.	Avanish Kumar et al (2014)	57.35	29.4	8.82	4.41
5.	**Present study**	**69**	**22**	**5**	**4**



INCIDENCE OF SEPTATE JUGULAR FORAMEN- BIPARTITE TYPE

R R Sturrock[40] (1988) in his study of 156 adult dry skulls observed septate JF with one septum, on right side in 4.5% and left side in 14.1% specimens.

MT Hatiboglu et al[30] (1991) did a study on 300 Anatolian skulls of 17th & 18th centuries and reported that in 8.2% the right JF had one septum whereas in 23.9% the left JF had one septum.

DR Sawyer et al[10] (2009) studied the bridging of JF in 234 skulls and reported septate JF with one septum in 8.1%. The right side showed a significantly higher occurrence than the left.

Shifan Khanday et al[48] (2013) studied 648 JF of 324 skulls and found out that right JF was bipartite in 36.3% and left JF in 24.1%.

Roma Patel et al[44] (2014) in their study of 100 dry skulls stated that 45% of the JF on right side and 39% on left side were bipartite.

Peiris HRD et al[18] (2014) analysed 75 dry skulls and reported that 84.7% of left JF and 80.6% of right JF were septate with one septum.

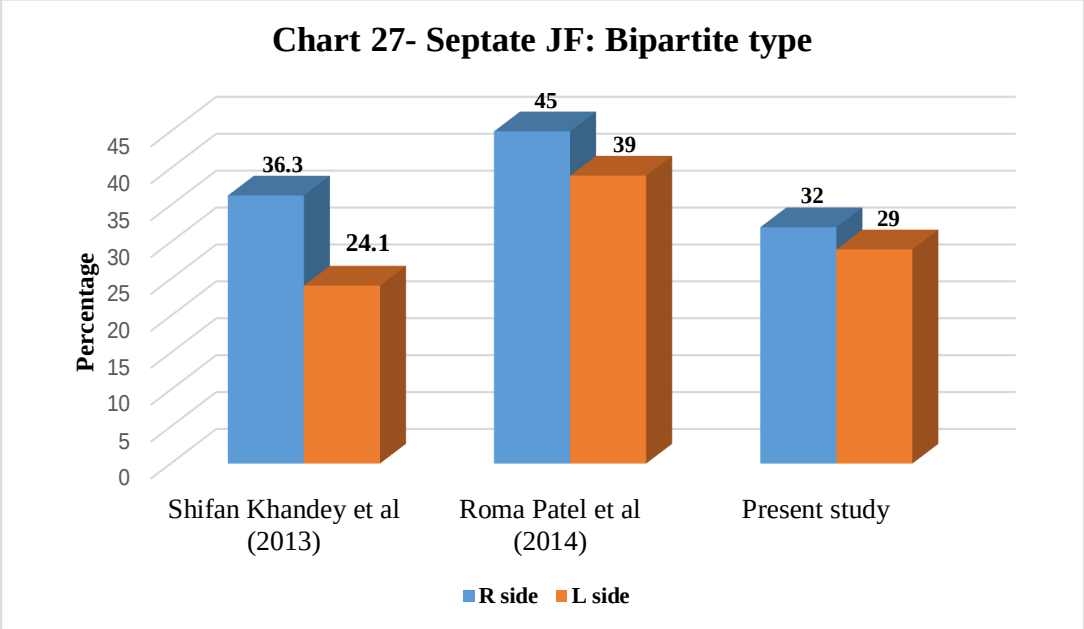
In the present study, the right JF was bipartite in 32% and the left was bipartite in 29%. The observations of the present study coincided with those of all these studies (Table 31) except those of foreign authors (RR Sturrock et al, MT Hatiboglu et al, DR Sawyer et al and Peiris HRD et al) probably due to racial differences in the skulls.

Insight on the incidence of septa can avoid their misinterpretation as abnormal bony growth leading to narrowing of JF. The JF has two vascular compartments that may be affected by tumour, laterally the jugular bulb where the sigmoid sinus continues as IJV and medially a passage for inferior petrosal sinus. Tumours may also penetrate the JF along the fibro-osseous diaphragm, which divides these two vascular channels.[29] Preservation of compartmentation signals the radiologists against neoplastic pathology of Jugular Foramen. Abnormally broad septa can accentuate the clinical presentation of JF tumours. The

compartmentation of JF might be a part of ongoing evolutionary process.[4,51] Hence this data is of relevance to radiologists, neurologists and neurosurgeons and anthropologists.

TABLE 31 SHOWING STUDIES WITH COMPARABLE INCIDENCE OF SEPTATE (BIPARTITE) JUGULAR FORAMEN.

Sl No.	Authors	Bipartite right JF	Bipartite left JF
1.	Shifan Khandey et al (2013)	36.3	24.1
2.	Roma Patel et al (2014)	45	39
3.	**Present study**	**32**	**29**



INCIDENCE OF SEPTATE JUGULAR FORAMEN- TRIPARTITE TYPE

H.L. Guido et al[19] (1997) studied 100 Brazilian skulls and stated that the JF was tripartite on right side in 6% and left in 5%.

I Tekdemir et al[21] (2001) studied 80 JF of 40 dry skulls and reported that one JF (1.25%) was divided anatomically into three parts.

Ruchira Sethi et al[45] (2011) analysed 56 adult dry skulls and reported presence of tripartite JF in 10.7% skulls bilaterally.

Anjali Singla et al[4] (2012) studied 50 adult dry skulls and reported 6% of specimen to have tripartite JF bilaterally.

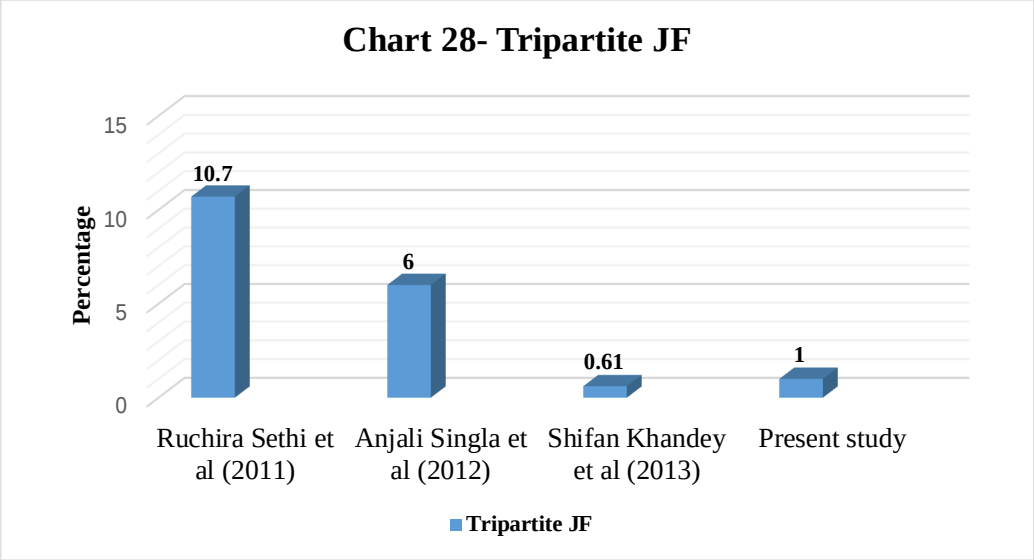
Shifan Khanday et al[48] (2013) analysed 324 skulls and found out that 0.61% had tripartite JF bilaterally.

In the present study, tripartite Jugular Foramen was observed bilaterally in one skull (1%). The observations of the present study were coinciding with those of other studies (Table 32).

The tripartite JF has the third, vascular compartment for inferior petrosal sinus.[30,54] This type of compartmentalization may accentuate the clinical presentation of glomus tumour.[19]

TABLE 32 SHOWING STUDIES WITH COMPARABLE INCIDENCE OF TRIPARTITE JUGULAR FORAMEN.

Sl No.	Authors	Incidence of tripartite JF (%)
1.	Ruchira Sethi et al (2011)	10.7
2.	Anjali Singla et al (2012)	6
3.	Shifan Khandey et al (2013)	0.61
4.	**Present study**	**1**



TYPE OF SEPTUM IN THE JUGULAR FORAMEN:

TYPE OF SEPTUM IN BIPARTITE JF

R R Sturrock[40] (1988) studied 156 adult dry skulls and observed that right JF had one complete septum in 3.2% and one incomplete septum in 1.3% whereas left JF had one complete septum in 3.2% and one incomplete septum in 10.9% specimens. He also stated that the incomplete septa in life were probably completed by cartilage.

Ruchira Sethi et al[45] (2011) analysed 56 adult dry skulls and reported that of the septate right JF, 7.1% were partial septa and 10.7% were complete septa and of the septate left JF, 4.3% were partial septa and 10% were complete septa.

Shifan Khanday et al[48] (2013) analysed 648 JF of 324 skulls and found out that 12.6% of the right JF and 12.8% of the left JF had one complete septum. One partial septum was noticed in 23.7% of the right JF and 11.3% of the left JF.

Peiris HRD et al[18] et al (2014) analysed 75 dry skulls and reported that one complete septum was observed in 14.7% of left and 10.6% of right jugular foramina and partial septum was noticed bilaterally in 70% of skulls.

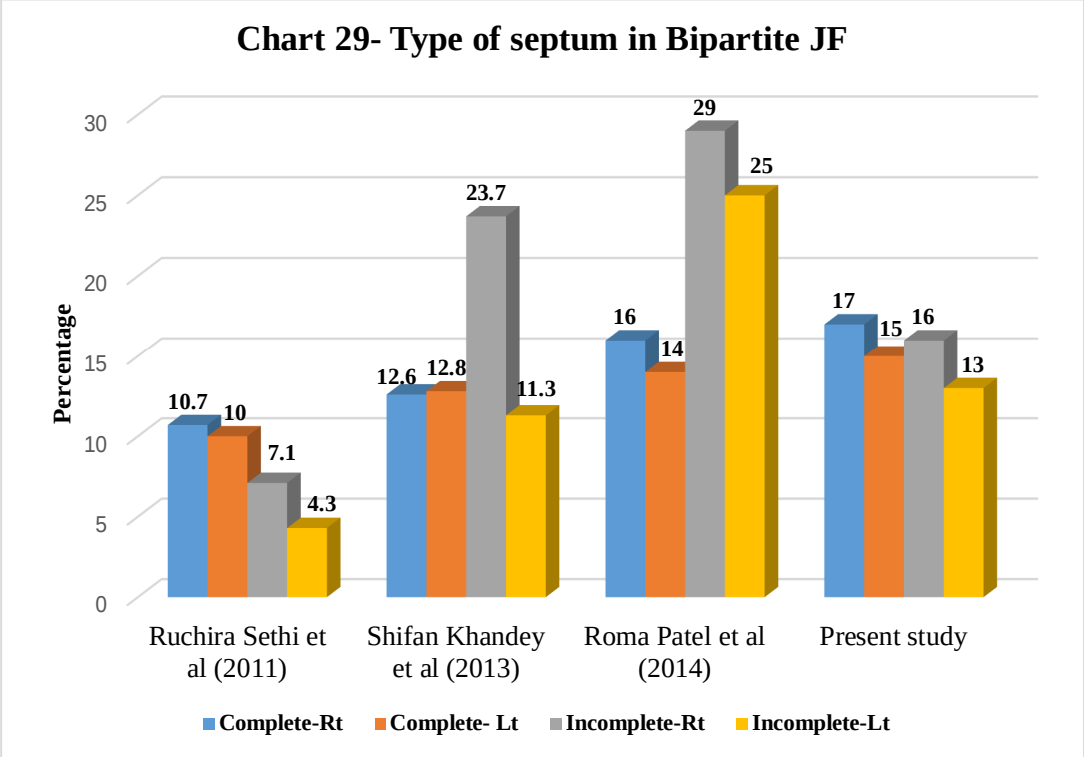
Roma Patel et al[44] (2014) in their study of 100 dry skulls stated that complete septum was present in 16% on right side and 14% on left side. Partial separation of JF was present in 29% of skulls on right side and in 25% on left side.

In the present study a complete septum was found in 17% of right and 15% of left JF. Incomplete septum was found in 16% of right and 13% of left JF. Observations of the present study were in concurrence with all these studies (Table 33) except those of foreign authors, RR Sturrock reported a lower incidence and HRD Peiris reported a higher incidence. This could probably be due to racial variations in the skulls.

In life the incomplete septa were probably completed by cartilage.[30,40] The difference in the anatomical nature and incidence of bridging can be attributed to factors like variability in bone formation around the primitive foramen lacerum posterior. The course of cranial nerves within the foramen may have anatomical variations, depending upon the bridging pattern and its types.[45]

TABLE 33 SHOWING STUDIES WITH COMPARABLE INCIDENCE OF TYPE OF SEPTUM OF JUGULAR FORAMEN.

Sl No.	Authors	Complete septum-R	Complete septum-L	Incomplete septum- R	Incomplete septum-L
1.	Ruchira Sethi et al (2011)	10.7	10	7.1	4.3
2.	Shifan Khandey et al (2013)	12.6	12.8	23.7	11.3
3.	Roma Patel et al (2014)	16	14	29	25
4.	**Present study**	**17**	**15**	**16**	**13**



TYPE OF SEPTA IN TRIPARTITE JUGULAR FORAMEN

In the present study, both the tripartite Jugular Foramina were partitioned by one complete septum and one incomplete septum. No literature could be found for comparison of the type of septa in tripartite Jugular Foramen.

PRESENCE OF ACCESSORY OPENING IN THE WALLS OF JUGULAR FORAMEN

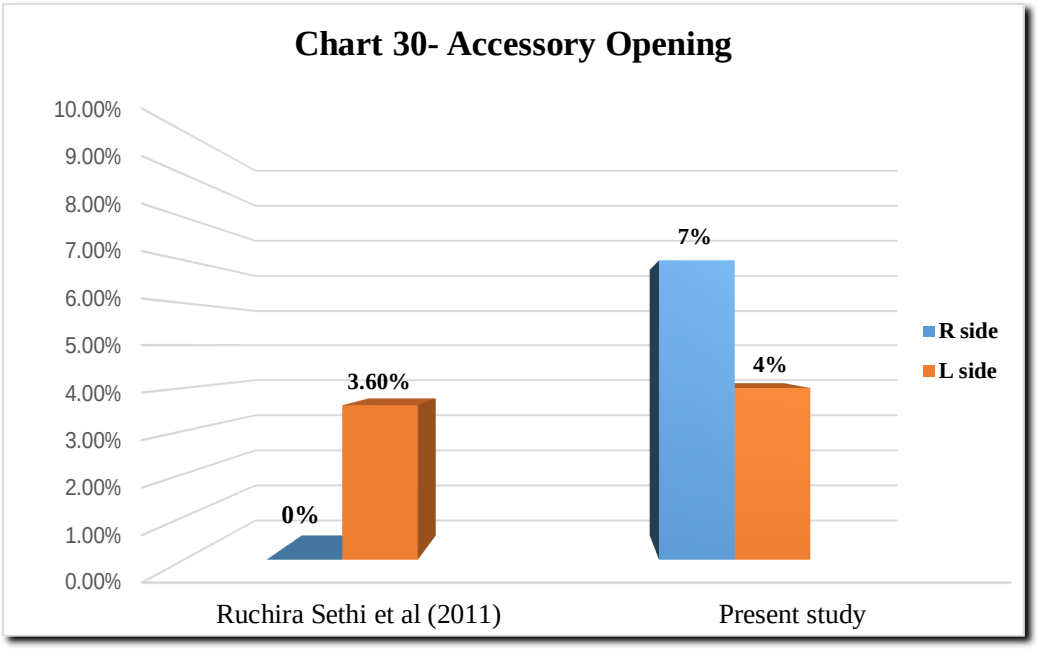
Ruchira Sethi et al[45] (2011) analysed 56 adult dry skulls and observed that in 3.6% skulls, an additional accessory foramen was observed in the posteromedial wall of JF, on left side only.

In the present study, accessory opening was found in the medial part of posterior wall of Jugular Foramen in 7% of skulls on right side and 4% on left side. The incidence on left side was similar to that of Ruchira Sethi et al (Table 34).

This may provide a potential source of communication of extracranial veins in the occipital region with sigmoid sinus. This channel can cause spread of infection from the region of scalp to intracranial dural venous sinuses, leading to thrombosis.[45]

TABLE 34 SHOWING COMPARISON OF INCIDENCE OF ACCESSORY OPENING IN THE WALLS OF JF.

Sl No.	Authors	Right JF	Left JF
1.	Ruchira Sethi et al (2011)	0%	3.6%
2.	**Present study**	**7%**	**4%**



SITE WHERE THE ACCESSORY OPENING LEADS TO.

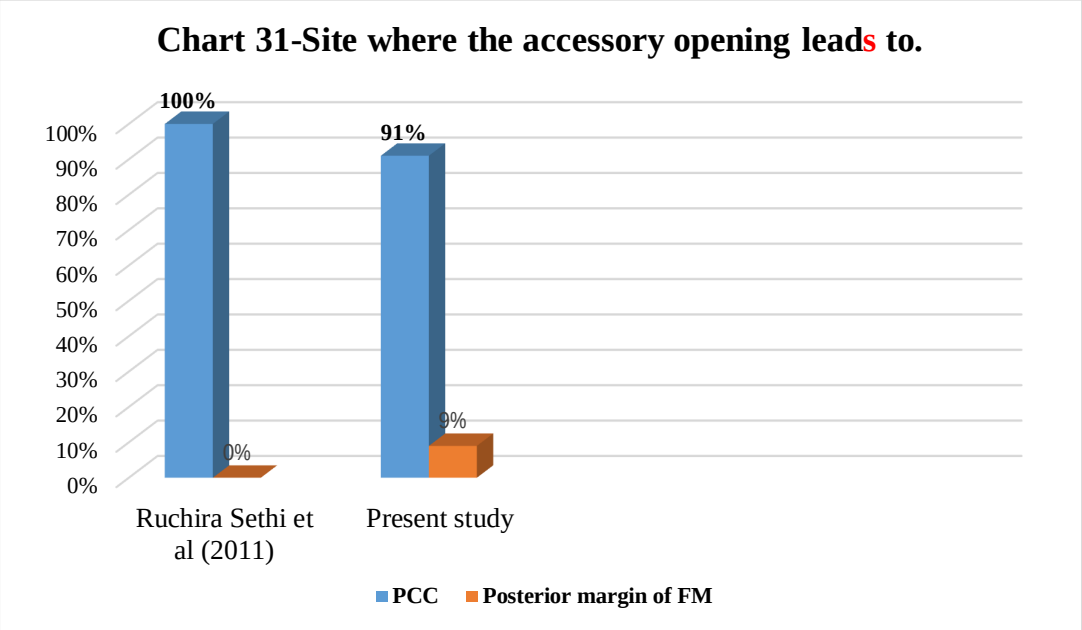
Ruchira Sethi et al[45] (2011) analysed 56 adult dry skulls and reported that the additional foramen observed in 3.6% of skulls was found to be communicating with the posterior condylar canal(PCC) as observed by passing a thin probe through it.

In the present study, out of the 11 accessory openings, ten (91%) led to the PCC. One accessory opening (9%) on the right side led to a canal which opened at the posterior margin of foramen magnum. The findings were similar to those of Ruchira Sethi et al, except for the latter 9%. The comparison is tabulated (Table 35).

Assessing this posterior fossa emissary vein preoperatively would allow one to modify the surgical procedure to reduce complications like life threatening bleeding or thrombosis of sigmoid sinus or IJV.[16]

TABLE 35- COMPARISON OF THE SITE WHERE THE ACCESSORY OPENING LEADS TO.

Sl No.	Authors	Posterior condylar canal	Posterior margin of Foramen Magnum
1.	Ruchira Sethi et al (2011)	100%	0%
2.	**Present study**	91%	9%



Conclusion

CONCLUSION

Need for thorough knowledge of the normal anatomy and variations of the Jugular Foramen has increased manifold during the last few decades owing to advancements in microsurgical techniques such as the lateral suboccipital approach. When well performed, the Jugular Foramen lesions are known to have reasonable cure rates. The ninth, tenth and eleventh cranial nerves further assign significance and complexity to this important cranial venous drainage area. A sincere effort was made to study in detail the morphological and morphometric features of the Jugular Foramen and the following conclusions were drawn.

- The mean mediolateral diameter of the Jugular Foramen was 14.87+/- 2.47mm on the right side and 13.76+/- 2.37mm on the left side.
- The mean anteroposterior diameter of the Jugular Foramen was 11.90 +/-1.93mm on the right side and 10.88+/-1.82mm on the left side. The mediolateral diameter and anteroposterior diameter of the Jugular Foramen exhibited positive correlation.
- The mean area of the Jugular Foramen was 179.23+/- 49.39mm^2 on the right side and 151.65+/-43.58mm^2 on the left side.

- The Jugular Foramen showed side dominance in most of the specimens. Right side was dominant in 69% and left side was dominant in 25%.
- The mean width of the Jugular Fossa was 7.90+/-1.80mm on the right side and 7.40+/-1.66mm on the left side.
- The mean depth of the Jugular Fossa was 11.20+/- 3.07mm on the right side and 10.05 +/- 2.85mm on the left side. The width and depth of the Jugular Fossa exhibited positive correlation.
- Jugular Foramen and Jugular Fossa exhibited statistically significant asymmetry in size.
- Domed Jugular Fossa was present bilaterally in 69%, unilaterally on the right side in 22%, unilaterally on the left side in 5% and was bilaterally absent in 4%. Absence of domed bony roof demands excess care during surgery since the jugular bulb has comparatively thinner wall.
- The Jugular Foramen was partitioned by one septum in 32% on the right side and 29% on the left side. The incidence of complete septum was 17% on the right side and 15% on the left side. The incidence of incomplete septum was 16% on the right side and 13% on the left side. Tripartite Jugular Foramen was present in 1% of skulls,

bilaterally. The bridging pattern may alter the relations of neurovascular structures within the Jugular Foramen.

- An accessory foramen was present in the posteromedial wall of the Jugular Foramen in 7% on the right side and 4% on the left side. In 91% it led to the posterior condylar canal and in 9%, the other end of the canal opened at the posterior margin of Foramen magnum. Preoperative assessment of the posterior cranial fossa emissary vein traversing through this canal is warranted for less intraoperative and postoperative complications.
- The findings of the present study supported the features of Jugular Foramen reported in the Indian subcontinent. The findings were found to be dissimilar to those of foreign studies suggesting racial and geographical differences in the features of the Jugular Foramen in different parts of the world.

Knowledge of morphometry, side dominance, anatomical nature and pattern of incidence of bony bridging of the Jugular Foramen is important for radiologists for accurate diagnosis and preoperative evaluation of lesions of the Jugular Foramen area. The database is relevant to neurosurgeons dealing with space occupying lesions in the Jugular Foramen. Insight into the dimensions of the Jugular Fossa and incidence of dome shaped roof is appreciable for otologists in surgical

practice as well as radiologists assessing the superior bulb of internal jugular vein. Hopefully this database would also be enlightening to anatomists and anthropologists.

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MASTER CHART

SKULL NO.	Rt MLD in mm	Lt MLD inmm	Rt APD in mm	Lt APD in mm	Rt AJF in mm2	Lt AJF in mm2	Rt FJW in mm	Lt FJW in mm	Rt FJD in mm	Lt FJD in mm	DOME Rt	DOME Lt	NO. OF SEPTUM Rt	TYPE OF SEPTUM Rt	NO. OF SEPTUM Lt	TYPE OF SEPTUM Lt	ACCESSORY OPENING Rt	SITE Rt	ACCESSORY OPENING Lt	SITE Lt.
1	17.12	15.02	10.23	9.32	175.14	139.99	5.89	5.51	11.32	8.12	P	P	0	-	0	-	A	-	A	-
2	13.25	13.96	12.87	11.64	170.53	162.49	5.82	6.98	11.45	12.23	P	P	1	INCOMPLETE	0	-	A	-	A	-
3	18.87	17.99	14.68	15.23	277.01	273.99	10.78	10.11	14.02	11.79	P	P	0	-	1	COMPLETE	A	-	A	-
4	13.23	14.34	10.23	11.32	135.34	162.33	6.03	7	9.39	10.21	P	P	0	-	0	-	A	-	A	-
5	15.9	10.34	11.45	7.58	182.06	78.38	8.79	5.12	14	8.25	P	A	0	-	0	-	A	-	A	-
6	14.79	9.75	15.05	11.34	222.59	110.57	9.02	6.23	13.25	11.98	P	A	0	-	0	-	P	PCC	A	-
7	19.22	17.67	15.89	10.68	305.41	188.72	10.23	10.98	10	10.6	P	P	1	COMPLETE	1	COMPLETE	A	-	A	-
8	15.35	11.32	9.76	10	149.82	113.20	8.23	7.23	8.26	5.37	P	P	1	INCOMPLETE	1	INCOMPLETE	A	-	A	-
9	12.88	10.42	11.34	7.84	146.06	81.69	5.02	6.12	7.3	11.98	P	P	0	-	1	INCOMPLETE	A	-	A	-
10	16.76	11.68	9.68	11.23	162.24	131.17	6.32	5.98	9.12	6.89	A	A	0	-	0	-	A	-	A	-
11	18.06	16.73	14.57	11.76	263.13	196.74	11.79	9.34	13.78	8.6	P	P	1	INCOMPLETE	1	INCOMPLETE	A	-	A	-
12	18.76	15	11.54	11.12	216.49	166.80	10.54	9.12	12.11	12.32	P	P	0	-	0	-	A	-	A	-
13	17.73	16.74	15.67	15.23	277.83	254.95	11.45	10.23	14.95	10.31	P	P	1	COMPLETE	0	-	A	-	P	PCC
14	17.94	13.85	9.83	8.23	176.35	113.99	13.34	6.59	10.02	6.69	P	P	0	-	1	INCOMPLETE	P	PCC	A	-
15	13.33	11.11	10.68	10.52	142.36	116.88	10.68	8.36	14.78	14.82	P	P	1	COMPLETE	1	COMPLETE	A	-	A	-
16	18.42	18.42	14.04	14.04	258.62	258.62	8.98	8.87	8.79	15.01	A	P	0	-	1	COMPLETE	A	-	A	-
17	14.32	13.32	11.68	9.68	167.26	128.94	6.79	5.79	6.73	8.23	P	P	0	-	0	-	A	-	A	-
18	10.65	8.34	10.93	9.63	116.40	80.31	5.32	5.71	7.6	8.48	P	P	0	-	0	-	A	-	A	-
19	16.76	15.43	14.24	10.54	238.66	162.63	6.98	7.12	13.17	7.61	P	P	0	-	0	-	A	-	A	-
20	16.88	17.66	11.79	8.75	199.02	154.53	5.45	5.93	10.29	10.32	P	P	1	INCOMPLETE	1	INCOMPLETE	A	-	A	-
21	12.78	13.76	12.52	10.6	160.01	145.86	9.12	8.79	10.31	8.89	P	P	1	COMPLETE	1	INCOMPLETE	A	-	A	-
22	13.08	14.23	11.25	9.82	147.15	139.74	9.22	10.12	7.59	9.71	P	P	0	-	0	-	A	-	A	-
23	14.68	14.68	11.89	11.89	174.55	174.55	7.02	9.23	9.93	11.21	P	P	0	-	0	-	A	-	A	-
24	11.88	13.77	9.58	11.61	113.81	159.87	6.43	11.12	9.21	15.91	A	P	1	COMPLETE	1	COMPLETE	A	-	A	-
25	16.66	12.76	12.59	8.54	209.75	108.97	9.27	7.35	14.21	7.6	P	A	0	-	0	-	A	-	A	-
26	13.04	12.67	11.53	10	150.35	126.70	7.12	8.38	16.31	8.81	P	A	0	-	0	-	A	-	A	-
27	14.98	13.44	14.82	10.56	222.00	141.93	8.67	8.24	9.79	5.32	A	A	1	INCOMPLETE	1	INCOMPLETE	A	-	A	-
28	16.34	10.76	12.32	8.94	201.31	96.19	7.12	5.45	10	11.89	P	P	0	-	0	-	A	-	A	-
29	15.22	15.65	11.05	11.87	168.18	185.77	8.89	8.37	8.61	8.41	P	P	0	-	1	INCOMPLETE	A	-	A	-
30	15.79	11.76	11.57	7.48	182.69	87.96	7.24	9.12	11.72	9.72	P	A	0	-	0	-	A	-	A	-
31	20.06	17.5	15.45	9.59	205.41	167.83	8.26	7.79	9.38	8.45	P	A	0	-	0	-	A	-	A	-
32	14.13	9.67	13.47	12.24	190.33	118.36	7.12	6.12	10.02	9.61	P	P	0	-	0	-	A	-	A	-
33	15.11	15.11	14.84	14.84	224.23	224.23	7.23	8	11.12	8.79	P	A	1	COMPLETE	1	INCOMPLETE	A	-	A	-
34	16.08	13.85	15.43	12.4	248.11	171.74	8.03	6.23	11	10	P	P	0	-	0	-	A	-	A	-
35	10	8.88	10.32	9.59	103.20	85.16	5.37	4.69	9.32	7.32	P	P	1	INCOMPLETE	0	-	A	-	P	PCC
36	15.13	13.67	13.77	12.51	208.34	171.01	8.28	7.92	10.42	9.45	P	P	1	COMPLETE	0	-	A	-	A	-
37	18.88	14.67	14.66	11.12	276.78	163.13	11.12	7.19	14.11	12.68	P	P	1	INCOMPLETE	1	COMPLETE	A	-	A	-

38	15.98	15	13.42	8.93	214.45	133.95	8.03	6.04	17.2	8.71	P	A	1	COMPLETE	1	INCOMPLETE	A	-	A	-
39	13.88	10.56	11.23	10.03	155.87	105.92	9.12	7.2	7.6	6.54	P	P	0	-	0	-	A	-	A	-
40	11.93	15.77	8.32	10.3	99.26	162.43	5.23	7.5	12.22	7.41	P	A	0	-	0	-	A	-	A	-
41	16.78	18.89	11.12	13.76	186.59	194.38	9.45	8.3	12.01	13.78	P	P	1	COMPLETE	1	COMPLETE	A	-	A	-
42	14.97	14.97	14.81	14.81	221.71	221.71	9.29	9.39	7.4	8.32	P	A	0	-	0	-	A	-	A	-
43	12.75	11.16	13	7.29	165.75	81.36	7.23	4.3	10.04	7.56	P	P	1	COMPLETE	1	COMPLETE	A	-	A	-
44	10.32	12.43	8.95	12.02	92.36	149.41	6.26	7.2	11.18	14.02	P	P	0	-	0	-	A	-	A	-
45	17.77	15.83	15.03	10.29	172.01	162.89	8.03	6.39	19.79	10.01	P	P	1	COMPLETE	0	-	A	-	A	-
46	12.86	16.42	10.68	12.23	137.34	200.82	6.43	8.2	8.59	17.57	A	P	0	-	0	-	A	-	A	-
47	17.07	15.22	11.34	9.28	193.57	141.24	7.17	6.29	10.35	9.91	P	P	1	COMPLETE	0	-	A	-	A	-
48	17.23	14.31	12.59	8.6	216.93	123.07	8.69	5.2	10.52	12.34	P	P	0	-	0	-	A	-	A	-
49	15.34	13.2	13.93	10.5	213.69	138.60	7.28	7.3	11.34	9	P	A	0	-	0	-	P	POST. FM	A	-
50	12.22	16.21	9.58	13.32	117.07	215.92	5.24	8.2	5.31	9.53	P	P	1	COMPLETE	0	-	A	-	A	-
51	17.21	9.02	12.57	9.23	216.33	83.25	8.89	5	17.32	8.78	P	A	0	-	0	-	A	-	A	-
52	17.68	14	11.58	11.82	204.73	165.48	6.68	5.2	12.32	13.02	P	P	0	-	0	-	A	-	A	-
53	12.86	10.65	10.24	12.5	198.69	133.13	6.69	4.79	9.32	8.45	A	A	0	-	0	-	A	-	A	-
54	12.79	13.21	10	10.29	127.90	181.77	5.89	7.8	10.41	17.68	P	P	0	-	0	-	A	-	A	-
55	15.32	14.32	12.45	12.02	190.73	172.13	10.14	9.2	6.32	7.54	P	P	0	-	0	-	A	-	A	-
56	12	11.91	11.03	12.3	132.36	146.49	7.59	8.1	10.32	10.89	P	P	1	INCOMPLETE	0	-	A	-	A	-
57	16.33	12.67	11.43	11.43	186.65	144.82	6.12	5.3	9.69	7.76	P	P	1	COMPLETE	1	COMPLETE	A	-	A	-
58	9.24	12.89	7.59	10.62	70.13	136.89	5.78	7.92	8.32	10.81	A	P	0	-	0	-	A	-	A	-
59	10.77	14.03	9.25	10.78	99.62	151.24	6.16	8.2	10.32	8.31	P	P	0	-	0	-	A	-	A	-
60	16.44	14.73	12.94	11.12	212.73	163.80	7.03	6.3	12.32	7.56	P	P	0	-	0	-	A	-	A	-
61	14.32	12.84	11.12	10.23	159.24	131.35	7.69	6.26	9.82	6.34	P	P	1	INCOMPLETE	0	-	A	-	A	-
62	17.22	15.74	13.34	8.59	229.71	135.21	8.12	7.42	11.12	8.57	P	A	0	-	0	-	A	-	A	-
63	11.77	12.7	11.74	10.42	138.18	132.33	6.49	7.41	5.06	8.79	P	P	1	COMPLETE	1	COMPLETE	A	-	A	-
64	11.94	11.94	11.85	11.85	141.49	141.49	7.12	6.51	10	7.68	P	P	0	-	0	-	A	-	A	-
65	16.83	12.84	13.95	10	234.78	128.40	11.1	8.41	12.45	8.34	P	P	0	-	0	-	A	-	A	-
66	12.06	11.92	9.68	8.62	181.26	102.75	8.1	7.61	7.23	6.76	A	A	0	-	0	-	A	-	A	-
67	11.77	13.03	9.05	10.04	106.52	130.82	6.01	8.2	9.39	9.92	P	P	0	-	0	-	A	-	A	-
68	14.93	17	12.69	13.32	189.46	226.44	7.12	9.41	10.12	10.08	P	P	1	INCOMPLETE	0	-	A	-	A	-
69	15.04	9.81	10.64	9.23	160.03	90.55	9.12	7.49	13.01	10.2	P	P	1	INCOMPLETE	1	COMPLETE	A	-	A	-
70	13.88	11.69	9.58	8.6	132.97	100.53	8	6.28	10.93	11.12	P	P	1	INCOMPLETE	0	-	A	-	A	-
71	10.12	11.49	8.89	9.21	89.97	105.82	6.05	7.42	11.79	8	P	A	0	-	0	-	A	-	A	-
72	16.88	13.7	12.93	11.23	218.26	153.85	11.23	7.39	13.84	7.32	P	P	0	-	0	-	A	-	A	-
73	11.87	14.01	9.59	11.45	113.83	160.41	8.24	8.1	8.12	15.01	P	P	0	-	0	-	P	PCC	A	-
74	13.22	15.34	9.83	12.03	129.95	184.54	7.13	9	15.89	10.01	P	P	0	-	0	-	A	-	A	-
75	13.23	13.23	13	13	171.99	171.99	7.42	7.3	12.3	10.29	P	P	0	-	0	-	A	-	A	-
76	14.79	12.03	12.43	9.12	183.84	109.71	5.02	6.42	20.12	15.87	P	P	0	-	0	-	A	-	A	-
77	14.82	13.68	13.23	11.24	196.07	153.76	7.02	6.51	11.23	11.32	P	P	0	-	0	-	P	PCC	P	PCC
78	17.93	19.68	12.79	14.98	229.32	294.81	8.32	12.11	17.12	17.78	P	P	0	-	1	COMPLETE	A	-	A	-
79	18.12	14.01	13.26	11.12	240.27	155.79	10.87	7.29	11.3	8.65	P	P	0	-	0	-	A	-	A	-

80	11	10.23	10.12	9.49	111.32	97.08	7.32	4.39	7.21	7.36	P	A	1	INCOMPLETE	1	COMPLETE	A	-	A	-
81	13.94	13.05	9.26	7.86	129.08	102.57	9.21	5.3	11.32	6.78	P	A	0	-	0	-	A	-	A	-
82	16	13.69	10.14	8.69	162.24	118.97	8.23	7.41	13.19	10.01	P	P	2	1 COMPLETE, 1 INCOMPLETE	2	1 COMPLETE, 1 INCOMPLETE	A	-	A	-
83	11.57	12.68	12.45	10.51	144.05	133.27	9.23	10.2	8.8	9.99	P	P	1	INCOMPLETE	1	COMPLETE	P	PCC	P	PCC
84	12.11	13.89	11.84	13	143.38	180.57	10.32	10.82	7.79	11.29	A	P	0	-	0	-	A	-	A	-
85	13.21	11.93	11.42	14.02	150.86	167.26	6.12	5.41	10.12	7.68	P	A	0	-	0	-	A	-	A	-
86	17.56	15.92	14.34	11.16	251.81	177.67	10.02	9.3	21.79	15.92	P	P	0	-	0	-	A	-	A	-
87	19.02	18.25	15.23	11.76	289.67	214.62	7.27	6.5	15.18	16.92	P	P	1	COMPLETE	1	COMPLETE	A	-	A	-
88	11.12	12.35	9.65	10	107.31	123.50	5.12	6.82	9.82	6.38	P	A	0	-	1	INCOMPLETE	A	-	A	-
89	12.34	13.6	11.12	12.23	137.22	166.33	7.23	7.49	9.4	7.2	P	A	0	-	1	COMPLETE	A	-	A	-
90	13.91	10.59	10.32	9.23	143.55	97.75	5.23	4.3	9.54	6.3	P	A	0	-	0	-	P	PCC	A	-
91	16.84	17.5	10	10.02	168.40	175.35	8.23	10.45	8.59	11.26	P	P	0	-	0	-	A	-	A	-
92	15.9	14.32	13.03	10.56	207.18	151.22	7.12	6	15.59	14	P	P	0	-	0	-	A	-	A	-
93	16.74	16.01	9.32	10.83	156.02	173.39	11.32	6.12	10.3	11.26	P	P	0	-	0	-	A	-	A	-
94	15.93	11.02	10.74	8.82	171.09	97.20	6.12	5	14.69	8.53	P	A	0	-	0	-	A	-	A	-
95	16.83	15.49	13.42	10.54	225.86	163.26	9.12	7.23	9.93	10.29	P	P	0	-	0	-	A	-	A	-
96	16.92	14.69	14.85	15.01	251.26	220.50	9.02	9.42	15.2	9.43	P	P	0	-	0	-	A	-	A	-
97	13.21	16.02	9.73	12.21	128.53	195.60	6.12	7.23	13.12	11.3	P	P	0	-	0	-	A	-	A	-
98	17.03	15.7	11.37	11.16	193.63	175.21	10.23	8.34	10.2	12	P	P	1	INCOMPLETE	1	COMPLETE	A	-	A	-
99	15.04	15.62	12.83	12.02	192.96	187.75	7.6	7.24	11.12	13.29	P	P	1	COMPLETE	1	INCOMPLETE	A	-	A	-
100	16.03	14.63	13.42	12.21	215.12	178.63	8.65	6.34	12.23	6.39	P	A	0	-	0	-	A	-	A	-

KEY TO MASTER CHART

Rt MLD	-	Mediolateral diameter of right Jugular Foramen
Lt MLD	-	Mediolateral diameter of left Jugular Foramen
Rt APD	-	Anteroposterior diameter of right Jugular Foramen
Lt APD	-	Anteroposterior diameter of left Jugular Foramen
Rt AJF	-	Area of right Jugular Foramen
Lt AJF	-	Area of left Jugular Foramen
Rt FJW	-	Width of right Jugular Fossa
Lt FJW	-	Width of left Jugular Fossa
Rt FJD	-	Depth of right Jugular Fossa
Lt FJD	-	Depth of left Jugular Fossa
Dome	-	Presence of domed Jugular Fossa
No. of septum	-	No. of septum in Jugular Foramen
Type of septum	-	Type of septum in jugular foramen
Accessory Opening	-	Presence of accessory opening in the walls of Jugular Foramen
Site Rt.	-	Site where the right accessory opening leads to
Site Lt.	-	Site where the left accessory opening leads to
PCC	-	Posterior condylar canal
Post. FM	-	Posterior margin of Foramen Magnum